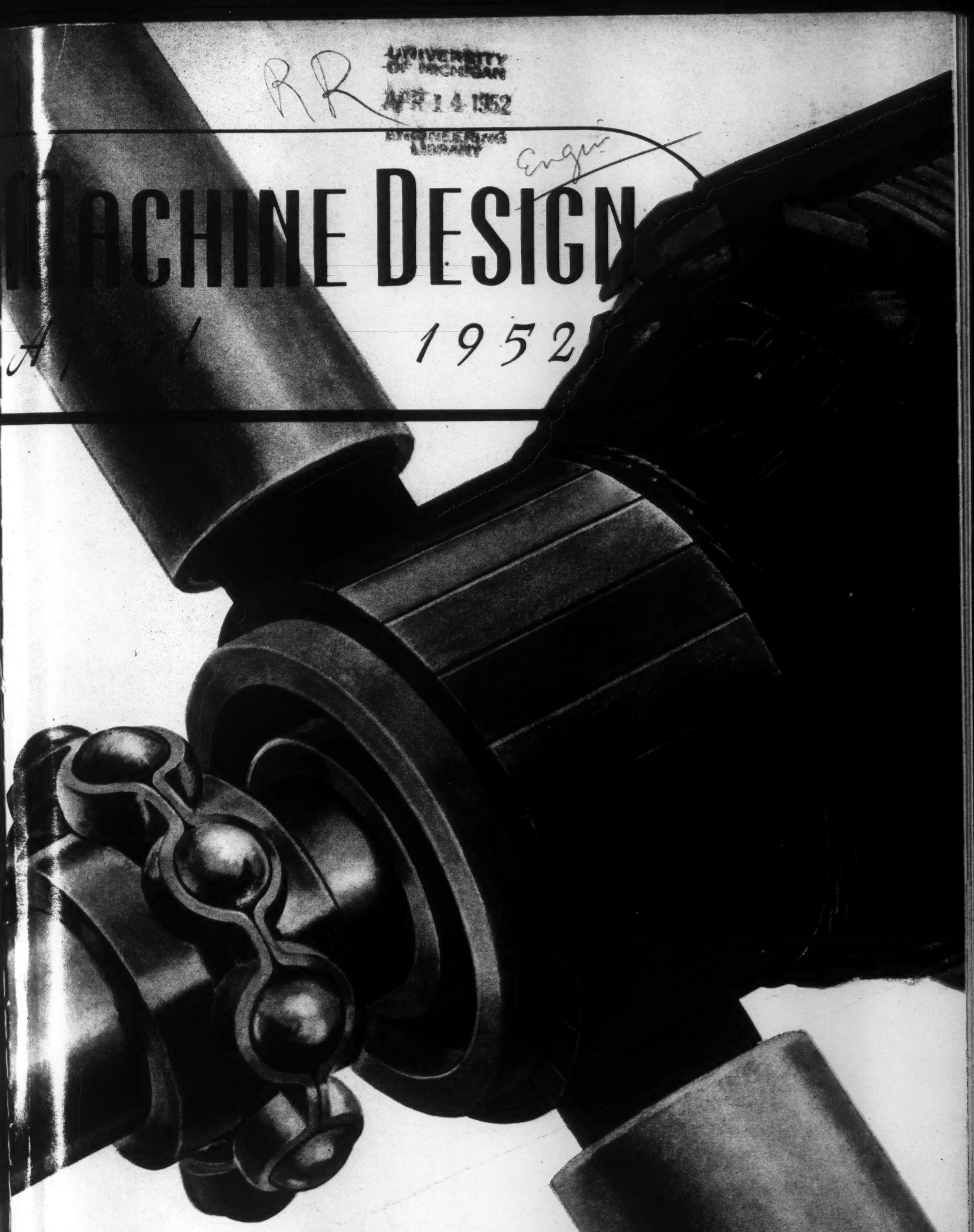
UNIVERSITY OF MICHIGAN
APR 14 1952
ENGINEERING LIBRARY

MACHINE DESIGN

April 1952



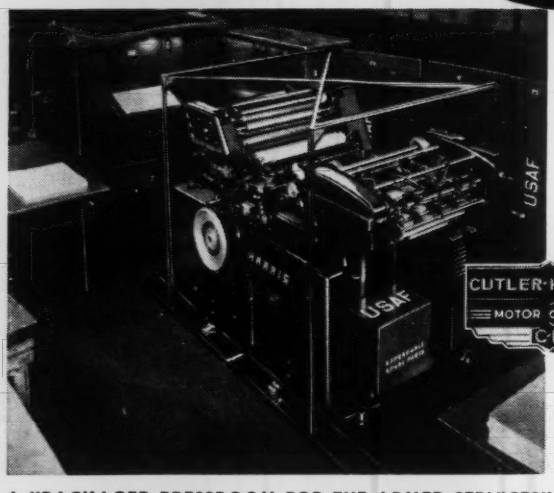
Drives and Controls

Contents, Page 3

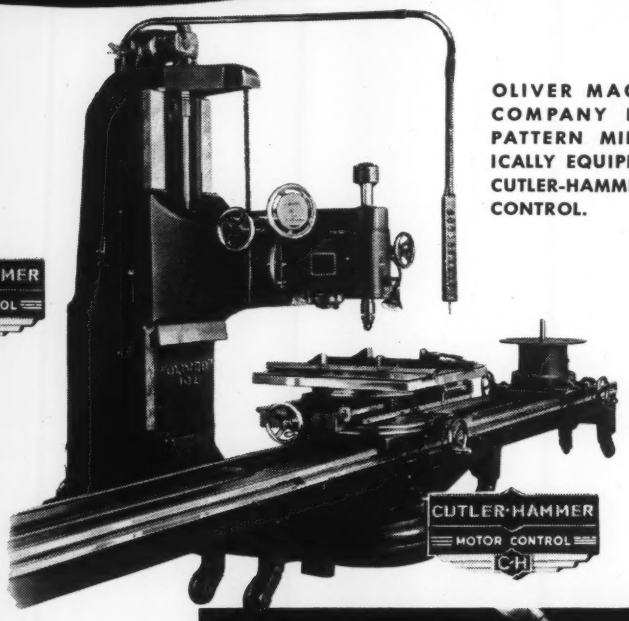
Choice of the Leaders

CUTLER-HAMMER
MOTOR CONTROL
C-H

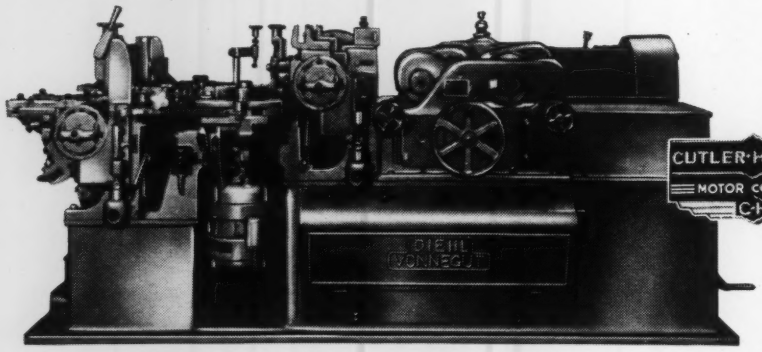
The Mark of Better Machines



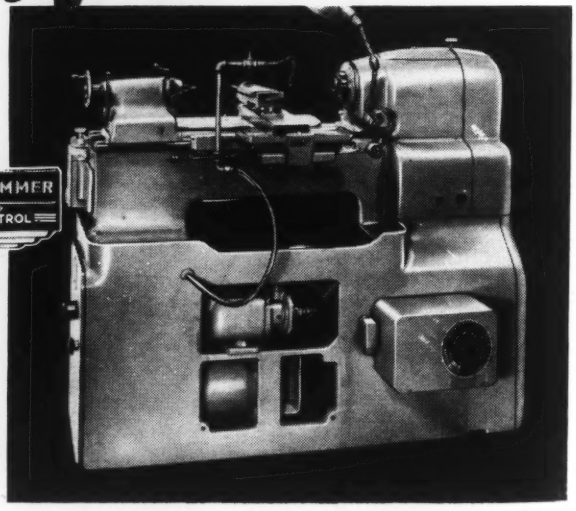
A "PACKAGED PRESSROOM FOR THE ARMED SERVICES" IS THE DESCRIPTION OF THIS FLYING PRESS MANUFACTURED BY HARRIS-SEYBOLD CO. AND 100% EQUIPPED WITH CUTLER-HAMMER MOTOR CONTROL. SHIPPING CONTAINER PROVIDES PRINTING WORKING SURFACES AND STORAGE FOR TOOLS AND ACCESSORIES.



OLIVER MACHINERY COMPANY NO. 102 PATTERN MILLER TYPICALLY EQUIPPED WITH CUTLER-HAMMER MOTOR CONTROL.



ONE OF DIEHL-VONNEGUT MOULDERS COMPLETELY EQUIPPED WITH CUTLER-HAMMER MOTOR CONTROL.



THE MONARCH MACHINE TOOL COMPANY'S TOOLMAKER'S LATHE COMPLETELY EQUIPPED WITH CUTLER-HAMMER MOTOR CONTROL.

Synonyms for Satisfaction

Company names that have become synonyms for satisfaction are names borne by products that consistently yield the highest degree of satisfaction in their users' hands. Such superior performance is no accident but is the result of a company policy of constantly searching for product improvements and scrupulously guarding every detail that influences the performance of the product in the users' hands. For such a company *NOT* to exercise the same exacting care in *purchasing* components used in its assemblies would be to contradict all it is trying to do and to undermine all it has so painstakingly built up. Thus the fact leading machinery builders do so frequently and continuously select Cutler-Hammer Motor Control for their machines says far more about Cutler-Hammer Motor Control than we can say . . . and far more convincingly. Let *your* choice be *Cutler-Hammer* Motor Control . . . *another* synonym for satisfaction. CUTLER-HAMMER, Inc., 1310 St. Paul Ave., Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ontario.

MACHINE DESIGN

THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS

Vol. 24—No. 4 **April 1952**

Let's Be Different (Editorial) 117

Hydraulic Drives—for takeup machine 118
By J. P. Greer

Contemporary Design 122
Cigar wrapping machine — telephone dialer

ELECTRIC MOTOR DRIVES 125
By John W. Greve

General Considerations 126

Mechanical Features 132

Electrical Characteristics 150

General Application Factors 184

Freewheeling Clutches—design and application factors 189
By Dietrich W. Botstiber and Leo Kingston

Pneumatic Geneva Mechanism—produces indexing motion 195
By Robert W. Ellms

All-Mechanical Torque Converter Drive 199
By L. D. Thostensen

Selection and Application of Control Timers in Machines 201
By V. C. Blecker

Long-Travel Hydraulic Drive—for high-speed traverse 208
By Richard E. Davis

Safety Control—for two-cycle gas engine 209
By M. C. Metzger

Design Abstracts 211
Free-piston engine — power steering — magnetic-particle clutch — hunting ideas — hydraulic aircraft drives — low-temperature steels — friction and wear

Over the Board 4
Topics 112
New Parts and Materials 214
Engineering Dept. Equipment 226
Helpful Literature 229
Men of Machines 232
The Engineer's Library 240
Noteworthy Patents 246
Stress Relief 256
Report on Materials 261
News of Manufacturers 310
Association Activities 318
Sales and Service Personnel 322
Sales Notes 330
Meetings and Expositions 334
New Machines 338
Itemized Index 7

EDITORIAL STAFF

COLIN CARMICHAEL
Editor

JOHN W. GREVE, *Associate Editor*
ROGER W. BOLZ, *Associate Editor*
BENJAMIN L. HUMMEL, *Associate Editor*
ELMAN R. DUNN, *Associate Editor*
ROBERT L. STEDFELD, *Assistant Editor*
LEO F. SPECTOR, *Assistant Editor*
JANE H. SMITH, *Assistant Editor*
FRANK H. BURGESS, *Art Editor*
LAURENCE E. JERMY, *Consulting Editor*

New York.....B. K. PRICE, L. E. BROWNE
Chicago.....ERLE F. ROSS
Pittsburgh.....DAN REEBEL
Detroit.....H. C. TUTTLE
Washington.....E. C. KREUTZBERG
London.....VINCENT DELPORT

BUSINESS STAFF

ROBERT L. HARTFORD
Business Manager

MARY L. CALLAHAN, *Advertising Service*
JACK C. GERNHARD, *Circulation Manager*

Chicago.....HOWARD H. DREYER
RICHARD K. LOTZ
New York.....RUSSELL H. SMITH
EDWARD S. LAWSON
JOHN W. EVANS
Cleveland.....JACK W. WALTON
Los Angeles.....F. J. FULLER
Griffin, Ga......FRED J. ALLEN

MAIN OFFICE

Penton Building, Cleveland 13, Ohio
Main 1-8260

Branch Offices

New York 17.....60 East 42nd St.
Murray Hill 2-2581
Chicago 11.....520 North Michigan Ave.
Whitehall 4-1234
Pittsburgh 19.....2837 Koppers Building
Atlantic 1-3211
Detroit 2.....6560 Cass Ave.
Trinity 5-3024
Washington 4.....1123 National Press Bldg.
Executive 6849
Los Angeles 48..6262 Commodore Sloat Drive
Webster 1-6865
Griffin, Ga......331 South Twelfth St.
London, S.W.1....2 Caxton St., Westminster

Published by
THE PENTON PUBLISHING COMPANY

E. L. SHANER.....*Chairman*
G. O. HAYS.....*President and Treasurer*
R. C. JAENKE...*Vice Pres., Director of Adv.*
F. G. STEINEBACH...*Vice Pres. and Secretary*
R. W. COLEMAN.....*Asst. Treasurer*

Also publisher of
Steel • *Foundry* • *New Equipment Digest*

Published on the seventh of each month. Subscription in the United States and possessions, Canada, Cuba, Mexico, Central and South America: One year $10. Single copies, $1.00. Other countries one year, $15.

Copyright 1952 by The Penton Publishing Company.

Acceptance under Act of June 5, 1934. Authorized July 20, 1934.

Over the Board

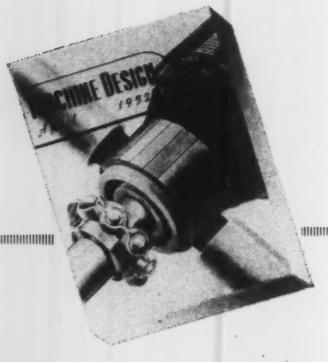
Washington Wisdom

An urgent call took us to Washington recently for an NPA conference of business paper editors on machine tools. We were informed that machine tools are a vital necessity in carrying out the defense program and heard several talks, including one by an Air Force lieutenant colonel who said in part:

"But it has always been something to me that I cannot see, with the extensive research and development problem that we have, and with the fast growing knowledge of aircraft, that you people who are industry are ever going to be able to keep up with your machine tools unless you constantly contact the people in Government service, such as you would have here, who can brief you on how to keep up with the type of tools we are going to have."

This Month's Cover

To symbolize the theme of this issue—drives and controls—the rotor of a universal motor is depicted on our cover. Playing no favorites between ac and dc motors, we selected this one because it operates equally well on either type of power supply. In creating his dramatic impression of this subject, artist George Farnsworth employed a GE motor for his "live" model.



Sausages and Pancakes

Truly an American breakfast, sausages and pancakes smothered with butter and maple syrup are

fit for the gods. When applied to electric motors, however, sausages and pancakes give the designer an opportunity to provide a drive to fit the exacting tastes of a particular machine. For close spindle mountings or for reduced inertia, the elongated sausage motor may prove the answer to an otherwise difficult problem. On applications where reduced length of a motor would permit more compact design and where increased inertia is either desirable or of no consequence, the pancake motor may prove to be the answer. These considerations along with other factors involved in selecting and specifying the exact motor for a particular drive are discussed in the special section on "Electric Motor Drives," Page 125.

Stress Relief

This phrase connotes some rather specific ideas relating to machines and structures, but starting this month it takes on a new meaning. "Stress Relief" is the title of a new department, Page 256.

As its title implies, this new column will be an informal outlet for nontechnical topics—in contrast to the heavier diet of our main content. While the servings will be lighter, they may prove no less satisfying—though on a more personalized basis. Personal attitudes and relationships will be among the targets. We hope you'll find a few worth-while tips in this and future installments.

Intermittent Mechanisms

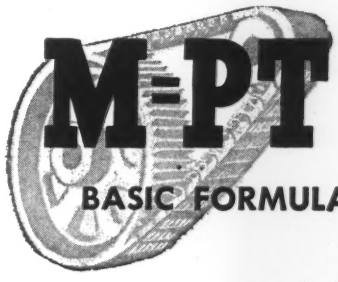
As announced last month, your response to the series of articles by Otto Lichtwitz on "Intermittent Mechanisms" has made it necessary for us to reprint the articles in order to satisfy your requests. These are arranged in an attractive 52-page booklet containing the complete four-part series. To help defray expenses we are charging a nominal price of one dollar per copy. If your set is incomplete or if you prefer to have the articles in a single package, just send your dollar to Book Dep't., MACHINE DESIGN, Penton Bldg., Cleveland 13, Ohio.

with help of MORSE Power Transmission Products

Heavy-duty Blaw-Knox Trukmixers carry tons of concrete aggregate on long or short hauls and mix batches of concrete on the job. The Trukmixers withstand ravages of sand, dust, rain, and mud. Despite unavoidable rough handling, they give long service life at extremely low operating cost.

In Trukmixer's power and transmission unit (details at left), a Morse Double-Width Roller Chain Drive and a Morse-Rockford Over-Center Clutch do their share of mixer's work dependably. They require a minimum of inspection and maintenance, help reduce expensive down-time, cut operating costs in many other ways.

Whatever your power transmission needs, turn to Morse as Blaw-Knox has. You can bank on dependable, economical operation and extra-long life from any product in the quality-built Morse line. That line includes the sensational Morse Hy-Vo Drives, Morse Roller Chains and Silent Chains, Morflex Couplings, Morse Chain Couplings, Morse Double-Pitch Roller Chains, and Morse Clutches. Let us send you information for the applications you have in mind.



Morse *means* Power Transmission

Morse Morflex Couplings

Morse-Rockford Clutches

Morse Morflex Drive Shafts

Morse-Rockford Pullmore Clutches

MORSE

MECHANICAL *POWER TRANSMISSION* PRODUCTS

PRODUCTS OF B-W BORG-WARNER

MORSE CHAIN COMPANY
7601 Central Ave., Dept. 300, Detroit 10, Michigan

MACHINE DESIGN **TOPICS**

. . . IN ENGINEERING AND RESEARCH

Back on the Gold Standard

Pure gold master blocks will soon serve as standards of surface finish. Developed jointly by Chrysler and General Motors, these gold masters will be used in manufacturing secondary specimens accurate to one millionth of an inch by an electroplating process. Sets of five replica blocks, representing the most commonly encountered values, will soon be available.

Thermal Indicators Made of Paper

Paper thermometers which change color at definite temperatures have been developed by the Army Quartermaster Corps for a temperature range of 115 to 500 F. Initially designed to ascertain thermal radiation of an atomic blast, the thermal indicator consists of a white pigment coating on black paper. At the designated temperature the white coating melts and disappears into the porous paper, revealing the black background.

"Catalytic" Engine Improves Gasoline Performance

A synthetically compounded catalyst, cast into the cylinder head or piston of a standard engine, can improve gasoline performance the equivalent of up to 24 octane numbers. According to Associated Research and Development Corp., use of a "catalytic" piston in a standard Cooperative Fuel Research engine raised the performance level of 76-octane gasoline to the equivalent of 100 octane. Engines with a 10 to 1 compression ratio are foreseen as a result of the development.

Potted Germanium Lightens Communications Equipment

Germanium transistors, tiny crystals of germanium "potted" or embedded along with electric contacts for use in place of standard radio tubes, can reduce the weight of portable radio-teletypewriter equipment, according to the Signal Corps. Weight of transistorized "converter" equipment, which changes radio signals to electric current for operating a teleprinter, can be reduced from 100 to 10 pounds. Transistors operate on about 1 per cent of the power required for vacuum tubes, thus permitting the substitution of ordinary dry-cell batteries for a heavy generator.

Precision Reticles on Transparent Film

Reticles for optical measurements are being produced with lines as fine as 1 micron and space between lines as close as 5 microns by the U. S. Testing Co. To manufacture the reticles a scale drawing is first reduced to the desired size on transparent film and is then enclosed in glass. Another current project involves the production of a linear scale accurate to within 0.00003-inch for a 2-foot overall length.

Losing Weight—by Flying

Any jet pilot interested in reducing can do it by following several easy steps, according to W. G. Schoolfield of Chance Vought Aircraft. First, he must fly at top speed, say about 690 mph. Second, he must fly due

The Name **Precision** *in "O" Rings*
is like Sterling on Silver

Precision Rubber Products
CORPORATION
The "O" Ring Specialists
Box 431, Dayton 1, Ohio

TOPICS

east at a constant altitude. By following this simple procedure, the weight of a 25,000-pound fighter plus pilot will decrease about 135 pounds. Reason is that the airplane is subject to centrifugal force which acts opposite to the earth's gravitational attraction. If the pilot were able to increase his speed to 16,800 mph the plane would weigh exactly zero.

Lighting System Uses 360-Cycle Current

Fluorescent lamps operating on 360-cycle current can generate 40 per cent more light than those operating on the usual 60 cycles, according to GE. In addition, tiny capacitors weighing only a few ounces can be substituted for conventional ballasts weighing several pounds. Auxiliary electronic equipment, or a magnetic converter, can step up the frequency.

Grease Has Wide Temperature Range

A use range of -80 to $+400$ F is reported for a new copper phthalocyanine lubricant by the Naval Research Laboratory. Tests of the grease on a high-temperature bearing test machine developed by the Laboratory indicate satisfactory operation for 1000 hours at 425 F.

All-Aluminum Honeycomb Used in Airframe Structures

An aluminum-foil honeycomb bonded with high-strength thermosetting resin adhesive to sheet aluminum facings provides an ideal material for airframe construction, according to the Glenn L. Martin Co. A core with a $\frac{3}{8}$-inch cell size is generally used. Successful applications include flooring panels, doors, access covers, ailerons, bulkheads and wing surfaces.

. . . IN GOVERNMENT AND INDUSTRY

Plastic Pipe Installed in Navy Minesweepers

Saving about two tons of critical copper per ship, plastic pipe made of glass-fiber cloth bonded with synthetic resin will be used in place of copper-nickel pipe on several new Navy minesweepers. Much less expensive than copper-nickel or stainless steel piping, the plastic pipe showed completely satisfactory corrosion, heat and shock resistance during an eight-month sea test aboard a destroyer escort.

Farm Machine Usage at Record Levels

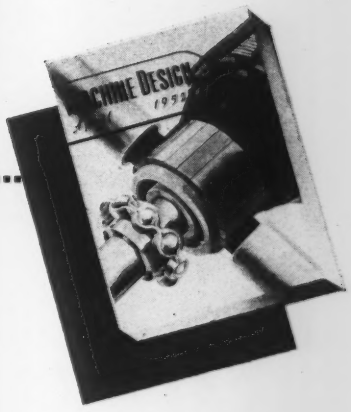
Preliminary estimates for 1951 show that usage of power machines on farms was at an all-time high during the year. Almost four million tractors were in operation, and use of grain combines, field corn pickers, motor trucks and milking machines increased appreciably.

SDPA Authority Grows

The Small Defense Plants Administration has taken over the principal functions of the NPA's Office of Small Business, a jurisdictional shift that is just one indication of this agency's recent rise to prominence among the defense agencies. Among the new duties of SDPA will be the furnishing of procurement assistance and managerial aids to small business, and the study of economic problems, size classification and production.

Standards Set for Industrial Gas Engines

Military specifications and standards for gasoline engines of 3 to 4-inch bore size will be available about July 1. The new standards, developed by the Munitions Board Standards Agency, replace almost 1200 different commercial parts with 59 standardized components. Currently, twelve manufacturers are building the engines for test purposes.



Let's Be Different!

THERE is a persistent myth that engineers are an unworldly breed of men possessed of uncanny competence in harnessing the forces of nature but somewhat removed from ordinary human life. It has even been said that although an engineer doesn't have to be queer, it helps.

Whatever justification there may have been for such notions, the complexities of modern industrial production leave little room for the development of such "characters" any more. To perform effectively the engineer today needs a knowledge of and contact with the world at least equal to and often broader than that of his counterpart in other lines of activity.

Any lingering doubts on this score are dispelled by a survey recently completed by the NSPE which disclosed that ninety-two per cent of a large group of industrial firms consider professionally trained engineers as potential general management executives. The remaining eight per cent, incidentally, were chiefly small concerns in nonengineering fields such as food, tobacco and novelty manufacturing.

An important factor in this consideration is attitude toward the job, as further revealed by the survey. Eighty-six per cent of the companies reported receiving numerous requests from their engineers for information on management policies. Significantly, the overwhelming majority of questions had to do with opportunities for advancement and with the company's plans for expansion and the development of new products and processes. By contrast, questions on benefits and security were few and far between, and indicated that engineers are much less interested in these aspects than are other industrially employed groups.

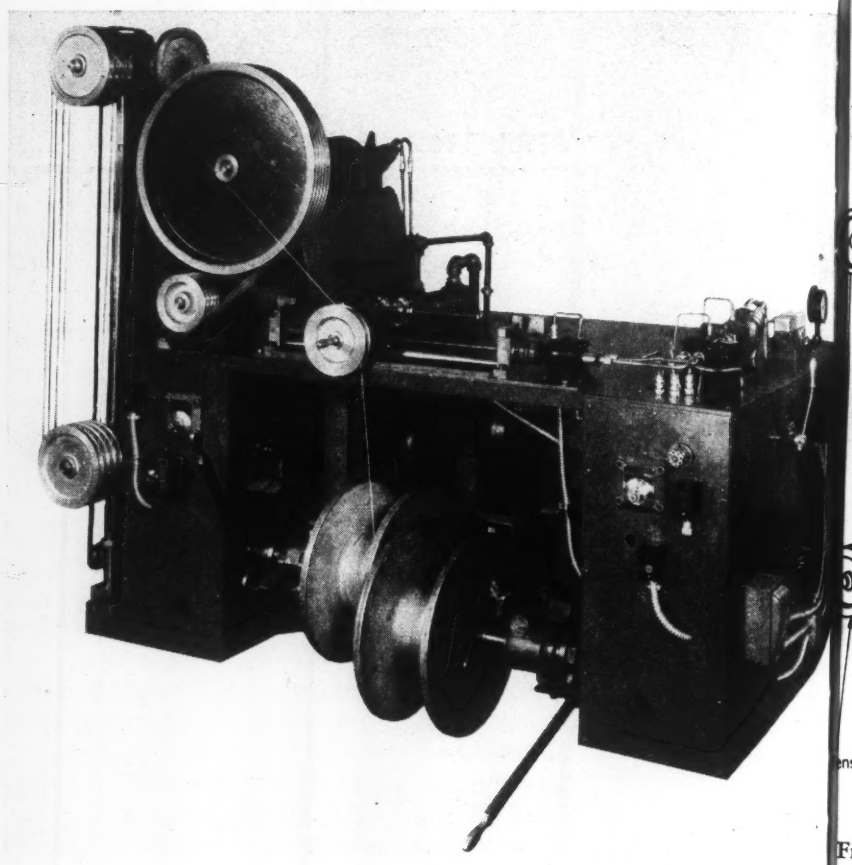
Perhaps, after all, engineers are "different." If the difference lies in attitude toward opportunity versus security, let us be proud of and jealously preserve that difference. As the French lawyer said when reminded that there is a difference between men and women, "Vive la difference!"

Colin Carmichael

EDITOR

Hydraulic Drives

. . . increase speed and accuracy of take-up machine



By J. P. Greer
Production Engineer
Industrial Ovens Inc.
Cleveland, Ohio

TO MEET the need for high-speed winding imposed by modern wire processing systems, the hydraulic take-up unit illustrated in *Fig.* 1 was conceived. This new machine—a combination capstan, tension control and take-up—propels and winds wire continuously at speeds which may vary between 100 and 3000 fpm to meet the requirements of the processing equipment. Also, all operating parts, *Fig.* 2, are readily accessible and easy to operate.

In high-speed winding the maintenance of tension and wire speed during winding and during crossover from full to empty reels is important. With the hydraulic system employed in this machine, wire tension is held constant at any desired value between a few ounces and hundreds of pounds. A higher reel speed is provided automatically when the wire is winding on the core of the reel than when it is winding near the rim of the flange. At the instant of crossover the empty reel is accelerated quickly to provide continuous operation.

For high-speed wire winding systems there is a choice of reeling mechanisms. Mechanical, variable-voltage, hydraulic or electronic control methods may be employed. Based on experience gained from many mechanical wire winding applications, a continuous high-speed unit should have:

1. Compactness and simplicity of design
2. Extreme range of speed adjustment
3. Reel drive power units which can operate in explosive and corrosive atmospheres
4. Motors which, when stalled and overloaded under severe conditions, can operate without serious damage.

All these requirements are incorporated in this hydraulic take-up machine which will wind various sizes of wire from 1/16 to ½-in. diameter and make crossovers at maximum wire speed without interrupting the winding process.

Basic Hydraulic System: A double variable-displacement piston pump drives four fluid motors as shown in the schematic drawing in *Fig.* 3. One side of the pump drives the hydraulic motor which powers the capstan unit. Speed of the capstan, which is line speed, is determined by the setting of a metering flow control valve in the pressure side of the circuit and a relief valve placed in the return line. This metering valve is manually set to the correct operating take-up speed.

Fig. 1—Left—Hydraulically operated constant-tension take-up machine provides continuous operation during reel changeover

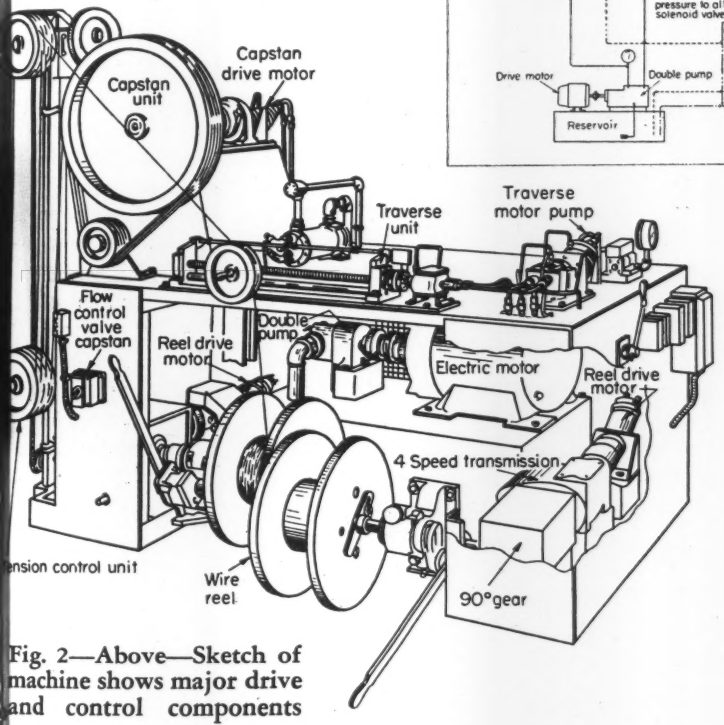


Fig. 2—Above—Sketch of machine shows major drive and control components

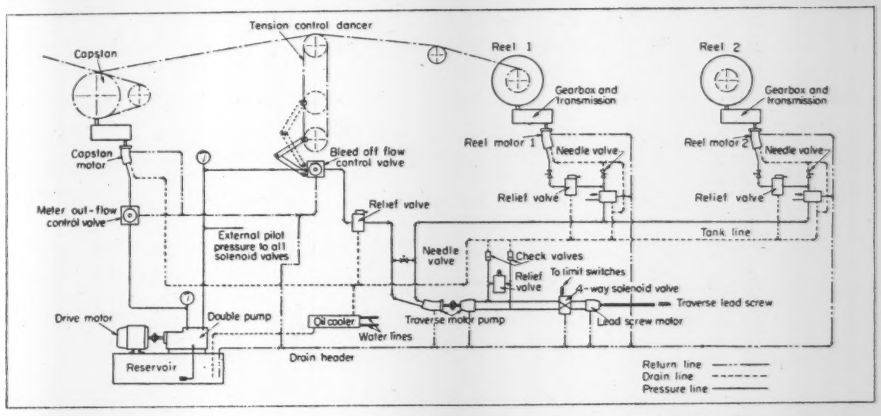
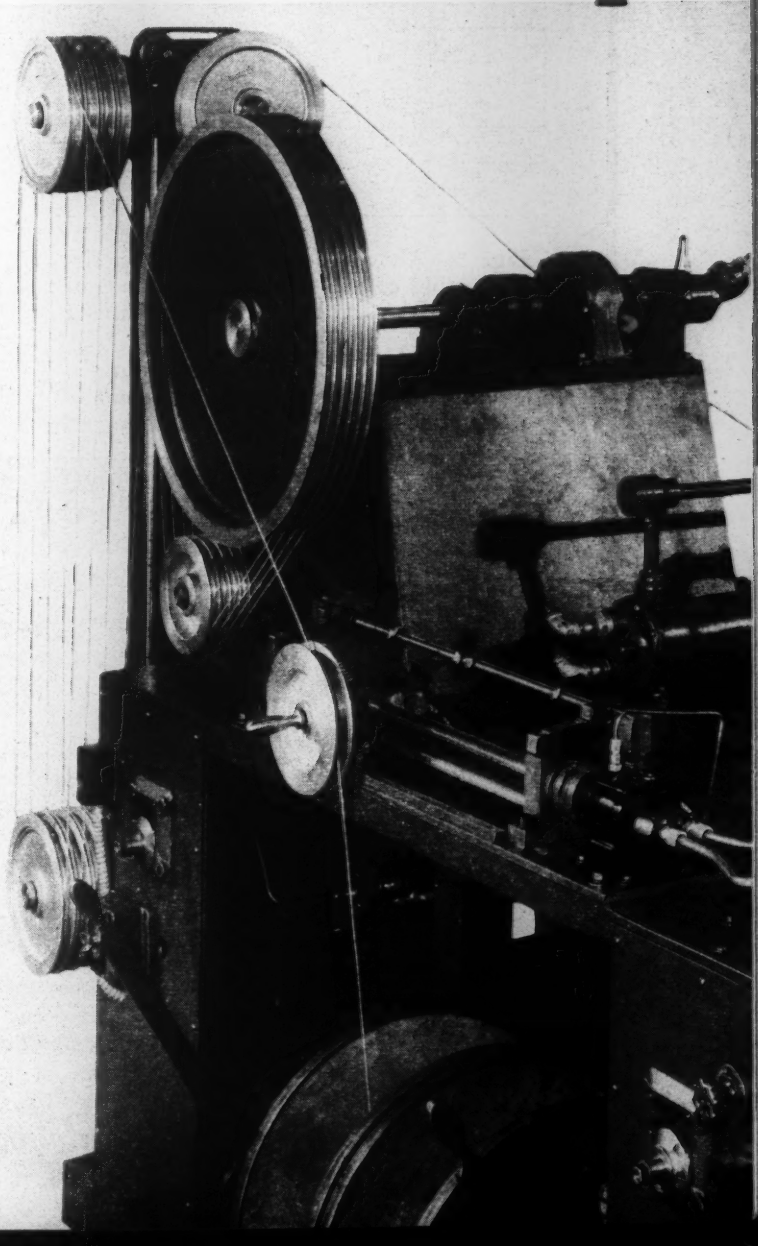


Fig. 3—Above—Hydraulic circuit illustrates how capstan and dancer control speed of windup. Traverse motions are obtained from auxiliary closed hydraulic circuit

Fig. 4—Below—Traverse unit employs reversing leadscrew powered by hydraulic motor which is controlled by 4-way solenoid valve



The other side of the variable-displacement pump provides input power for synchronizing the reel drives and traverse mechanism. Control of the windup reels with respect to wire build-up is made through a tension-control dancer. Free vertical movement of the lower sheave on the tension control unit operates a flow control valve by mechanical means. This regulates the oil that is delivered to the fixed-displacement fluid motors driving the two windup reels.

Traverse Unit: A closed circuit is utilized to drive the traverse lead screw, *Fig.* 4. This circuit is supercharged by a relief valve to replenish oil that is lost in the system. In the traverse unit, *Fig.* 3, the speed of the constant-displacement piston type motor varies with the reel build-up speed. This variable then is transferred to a variable-delivery hydraulic pump with handwheel control, *Fig.* 3, which powers a constant-displacement piston type motor to drive the lead screw.

In this closed circuit, leadscrew direction is changed by 4-way solenoid valves which are energized by limit switches located on the traverse mechanism frame. Integrated with the reel drives, this traverse operation provides a level lay on the wire regardless

of reel speed. To adjust the lay of wire due to size, the oil flow is regulated in the variable-delivery hydraulic pump having the manual control.

The leadscrew powers a feed sheave which travels on a carriage in a reciprocating path over the loading reel. At the end of the wire lay travel the traversing feed sheave support frame contacts a limit switch which energizes the solenoid valve, causing the fixed-displacement motor to reverse itself and thereby change the direction of rotation of the lead screw as indicated in the electrical circuit schematic in *Fig.* 5. This reciprocating motion is repeated until the reel is fully loaded.

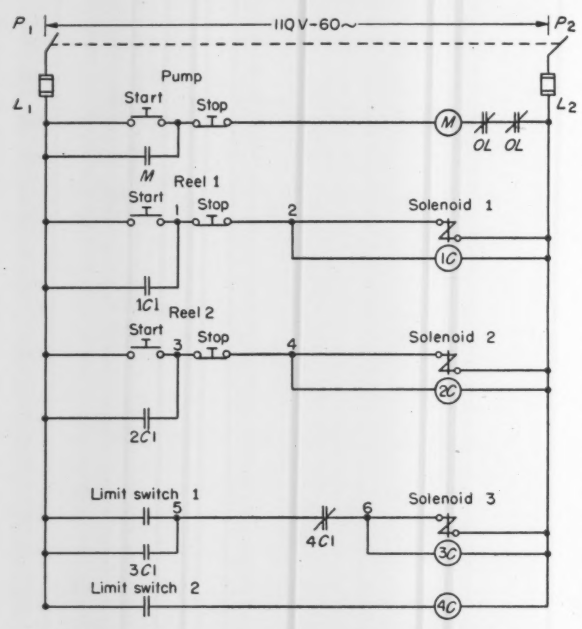


Fig. 5—Above—Schematic electric circuit shows controls for main pump motor, reel drives and traversing mechanism

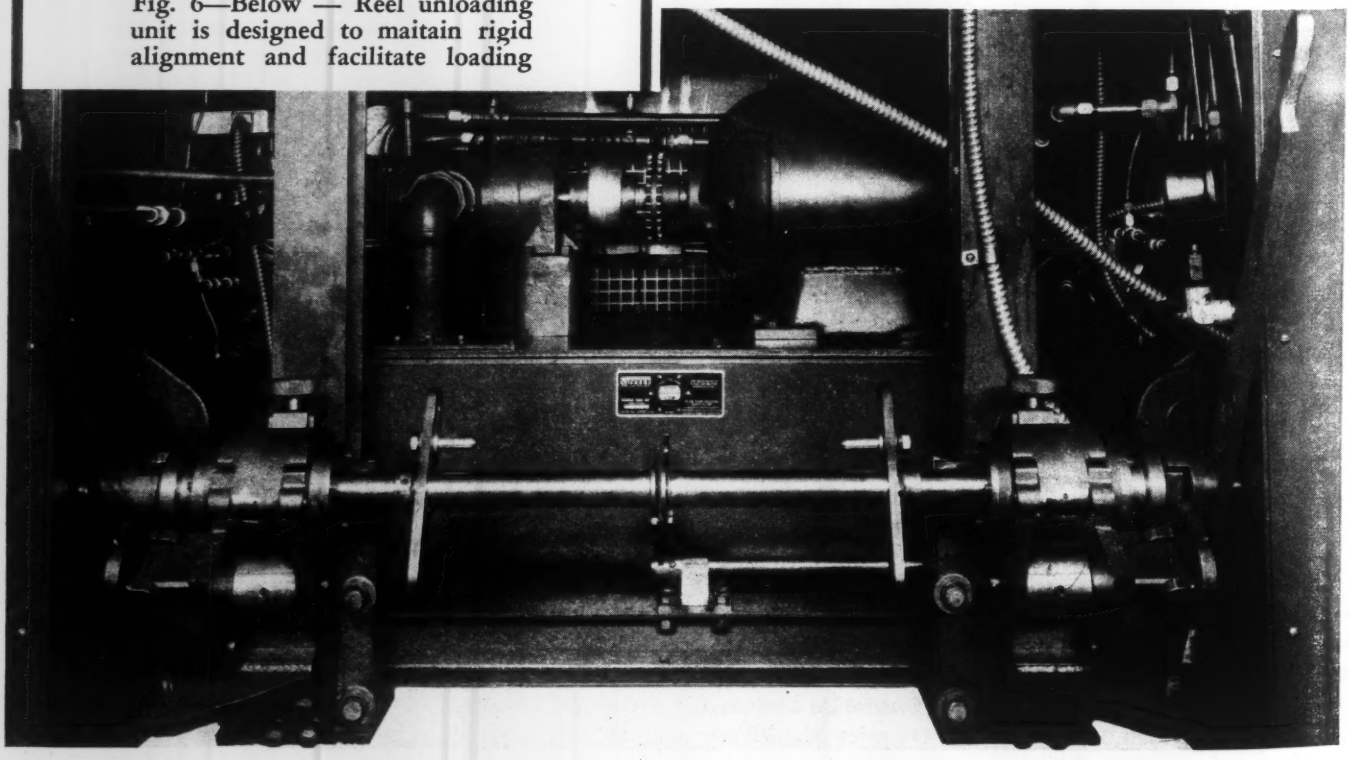
Fig. 6—Below — Reel unloading unit is designed to maitain rigid alignment and facilitate loading

One of the many problems which were involved in the design of the traverse unit was the redesign of the previous mechanical unit to hydraulic operation. In the mechanical powered traverse and crossover unit, a large diameter screw with reversing gear box was used. Reversing was accomplished by a double cast-iron cone clutch incased in a bath of oil. Clutch operations were effected by several snap-link motions. At normal operating speeds this was a practical unit but, at continuous high-speed operation, the mechanical tolerances required to give the proper functions for winding operations were prohibitive and resulted in problems in production, lubrication and maintenance.

The redesigned hydraulic traverse and crossover uses the same large diameter leadscrew but is powered by a directional fluid motor with a variable-displacement pump in series. Directional changes of the leadscrew are made through the 4-way solenoid valve.

Capstan: The metering element in any wire winding system is the capstan and all speed references are taken from it. To insure smooth propulsion of wire through the system, large diameter driving capstans with positive grip fleeter sheaves were designed. These capstan units are lightweight, accurately machined, and statically and dynamically balanced for top operating speed. The capstan unit is positioned for ease of threading and for convenient visual control in synchronizing the tension control unit with respect to reel build-up.

Reel Unloading: In high-speed wire handling the unloading of full reels is critical. Speed, ease of handling, and alignment of rotating parts are all prime



requisites. To meet these requirements an ingenious reel mounting and unloading unit, *Fig.* 6, was designed. The mechanism features a demountable shaft and bearing housing assembly supported by a heavy bearing mounting on a lever-operated tilting base. With this tilting device a full or empty reel is raised or lowered into operating position easily. This design provides for a minimum of reel flange distortion, prolongs reel life and results in better production.

In operation, four simple steps are involved in unloading and loading the heaviest reels.

1. WINDING: When the reel is winding, the assembly is in the operating position shown in *Fig.* 6. The reel shaft is accurately located, with the driving gear in mesh with its pinion, and is held in rigid alignment by a heavy keeper latch
2. RELEASING: After the reel is wound and the crossover accomplished, the reel drive is disconnected by a clutch directly over the reel bearing. The operator presses the reel lever slightly towards the reel and allows the handle to lower. When the reel flanges touch the floor, the operator turns the knurled keeper latch pin to effect actual release of reel
3. UNLOADING: After turning the keeper latch pin, the operator raises the latch to the upper limit, automatically opening the main reel bearing housing holder. When the full reel is on the floor with keeper and latch open and, with shaft still assembled, the reel is rolled from the machine for unloading
4. REMOVING: In the final step, the operator removes a collar from the end of the reel shaft and easily pulls the assembly from the reel. The shaft is then inserted in an empty reel and loaded into the machine by reversing these four steps. This reloads the machine for continuous winding.

Tension Control Dancer: The tension stand, *Fig.* 7, is a device which compares the amount of wire that is being fed into it with the amount of wire taken out. The difference between wire taken in and out is reflected by the position of the dancer sheave. This movement is used to control the hydraulically operated transmission which in turn controls the windup reel speed.

Without proper tension on the take-up reels, spooling the wire can be a difficult and time-consuming operation. Wire build-up will vary with the gage of wire being processed. This constant-tension hydraulic system is designed for ease of installation and maintenance and is arranged so that incoming wire can come from either side of the top sheave. Also, tension adjustments may be made while wire is in motion.

Crossover Mechanism: In the design of the high-speed crossover, an important feature in continuous operation, the use of manually controlled needle valves was incorporated. When one reel is nearly loaded, the other reel is powered to facilitate the crossover.

After a few revolutions of wire have been laid on the empty reel, a trigger cutter mounted between the dual reels is then used to cut the wire, while both reels are revolving. Since the crossover operation is semiautomatic, winding is therefore continuous, making higher production possible.

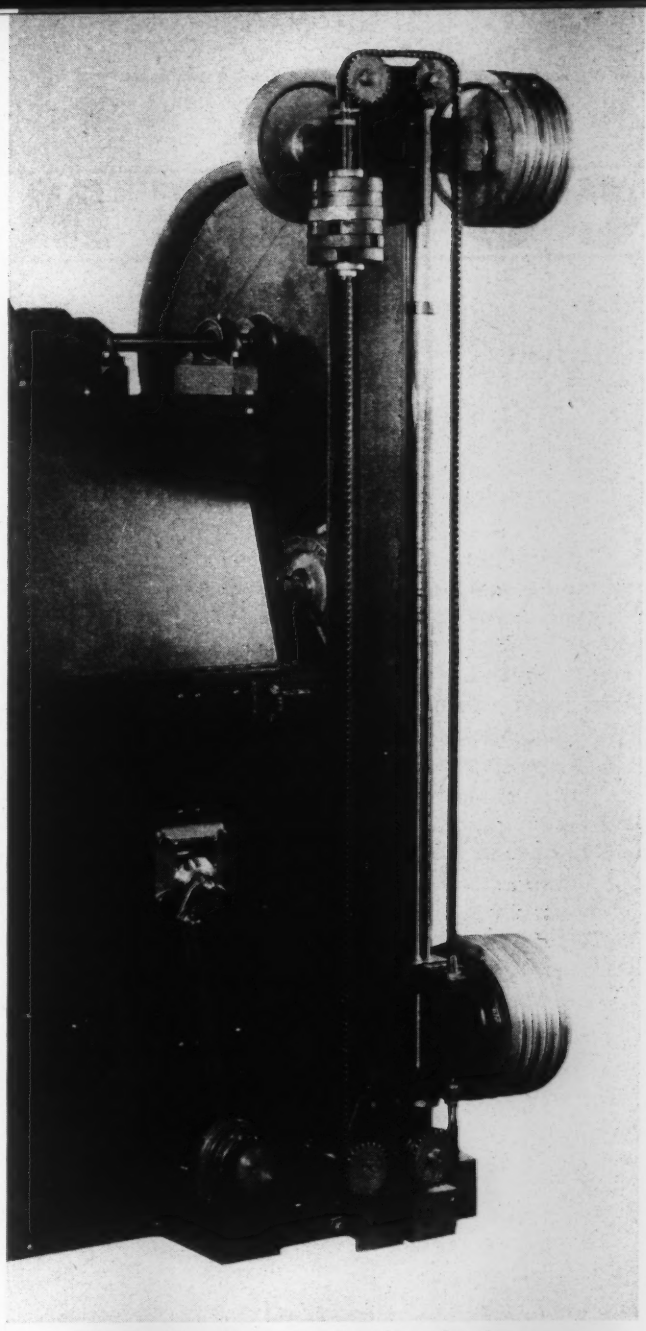


Fig. 7—Tension control unit maintains constant tension during windup. Corrections in speed to maintain tension are effected by valve position as the lower sheave travels downward or upward from normal

Cooler: Incorporated in the hydraulic system is a shell and tube heat exchanger placed in the return lines of the fixed displacement reel motors.

Summary: Wire processing imposes a variety of demands. The control of tension in a high-speed wire winding system is important and second only to speed control. Variations in tension affect coating qualities and tightness of wire as it is wound on final take-up reels.

For a system of this type detailed calculations of torques are not required. Given the tension and maximum diameter of full reels, the system can be sized on the basis of constant horsepower and variable speeds. The only requirement then is one of supplying units of maximum horsepower to rotate the reels against the tension loading of the wire plus allowances for drive and friction losses.

CONTEMPORARY

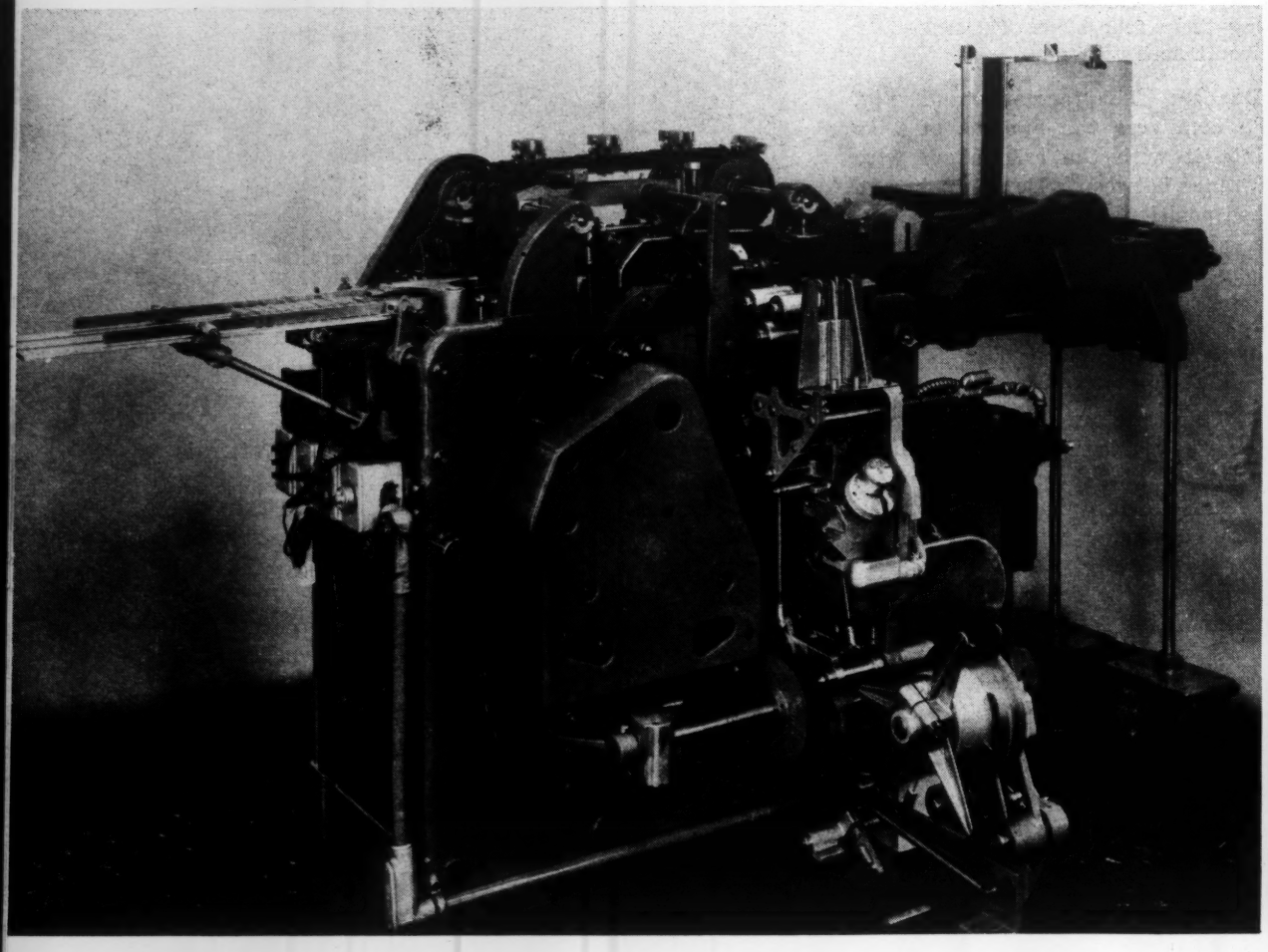
Wrapper Seals and Bands Cigars

CURRENT trend toward built-in adjustability in packaging machines is well illustrated by the cigar-wrapper shown below, left. Capable of handling from 100 to 120 cigars per minute—twice the speed of preceding machines—Package Machinery Co.'s model CWB is adjustable for cigar sizes ranging from $\frac{7}{16}$ to $\frac{7}{8}$-inch diameter and from four to six inches in length.

A Reeves variable-speed drive unit housed between the side frames, below, right, provides handwheel control for changing the speed of operation. To avoid the effects of possible misalignment, Heim spherical bearing rod ends are used on many of the connecting rods. Cups attached to the side frames beneath exposed shaft ends serve to catch excess lubricant from the bearings, thereby avoiding uncleanliness.

Both roller and tooth forms of chain, right, are used for timing the mechanisms and conveying the cigars through the machine. Spring-loaded fingers for handling the cigars are carried on extended roller pins of parallel transfer chains. Finger spacing can be altered on the chains which are shoe-guided between the sprockets to insure stable, straight-line movement of the fingers.

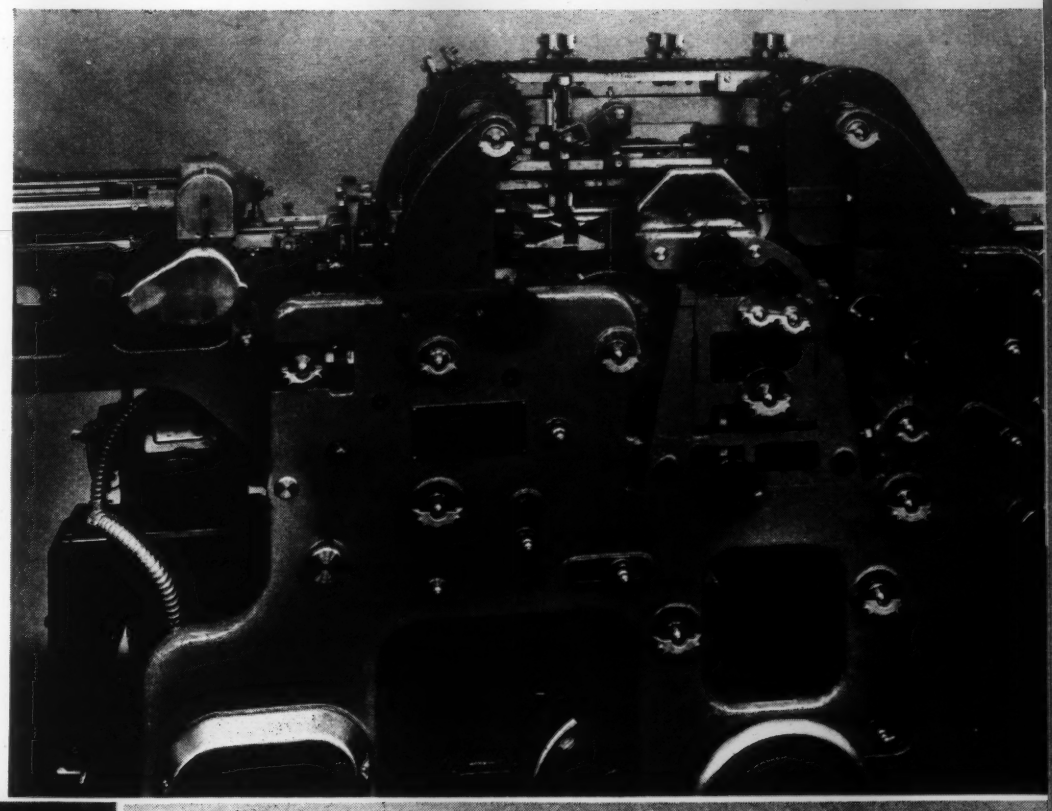
In operation, cigars are fed from the bottom of a loading hopper, below, center, onto the chain conveyor by means of a shuttle plate. Heat-sealing cellophane wrapping is fed into the machine from a storage reel. Enroute to the wrapping device, a precut printed band is glued in place on the cellophane wrapping stock. An arm vacuumized by Motoair pump handles the band. The stock is then slit in two places at the edge so that the band will automatically open the wrapper

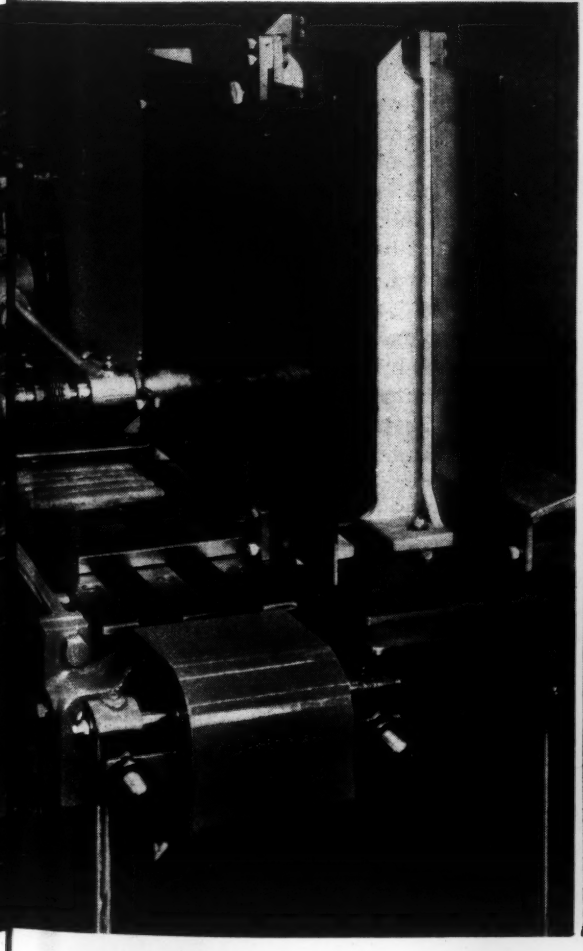


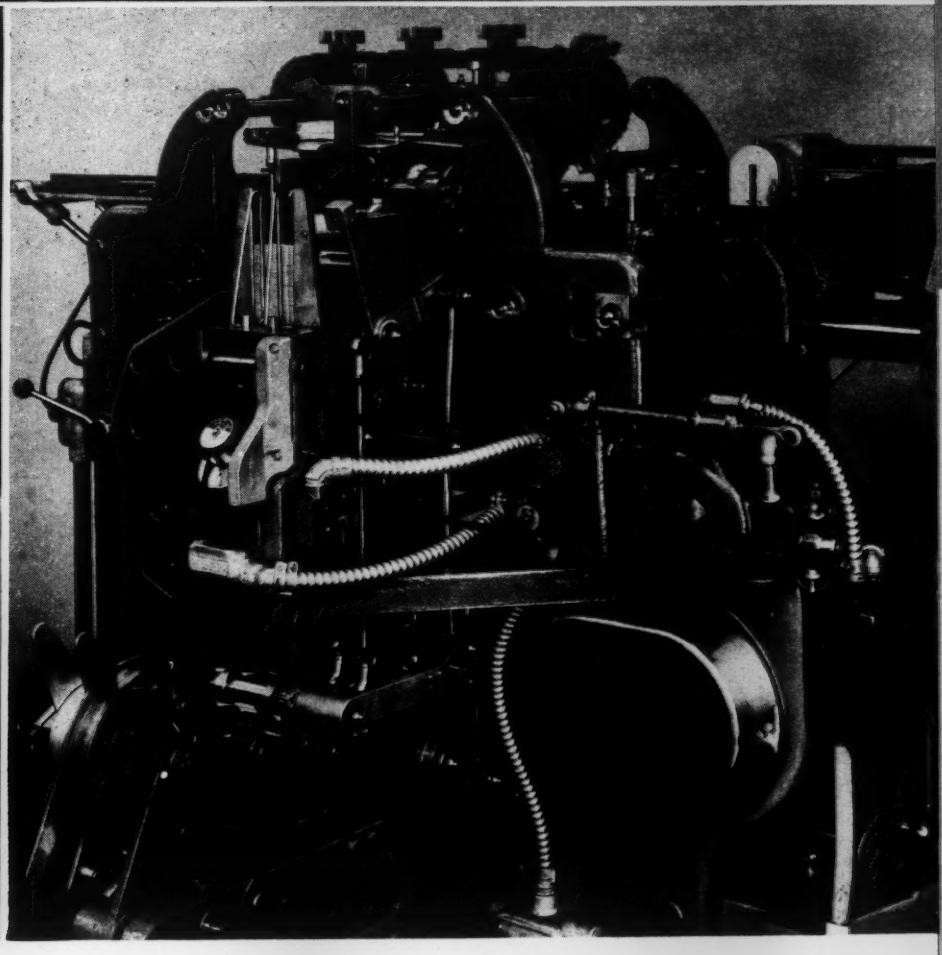
DESIGN

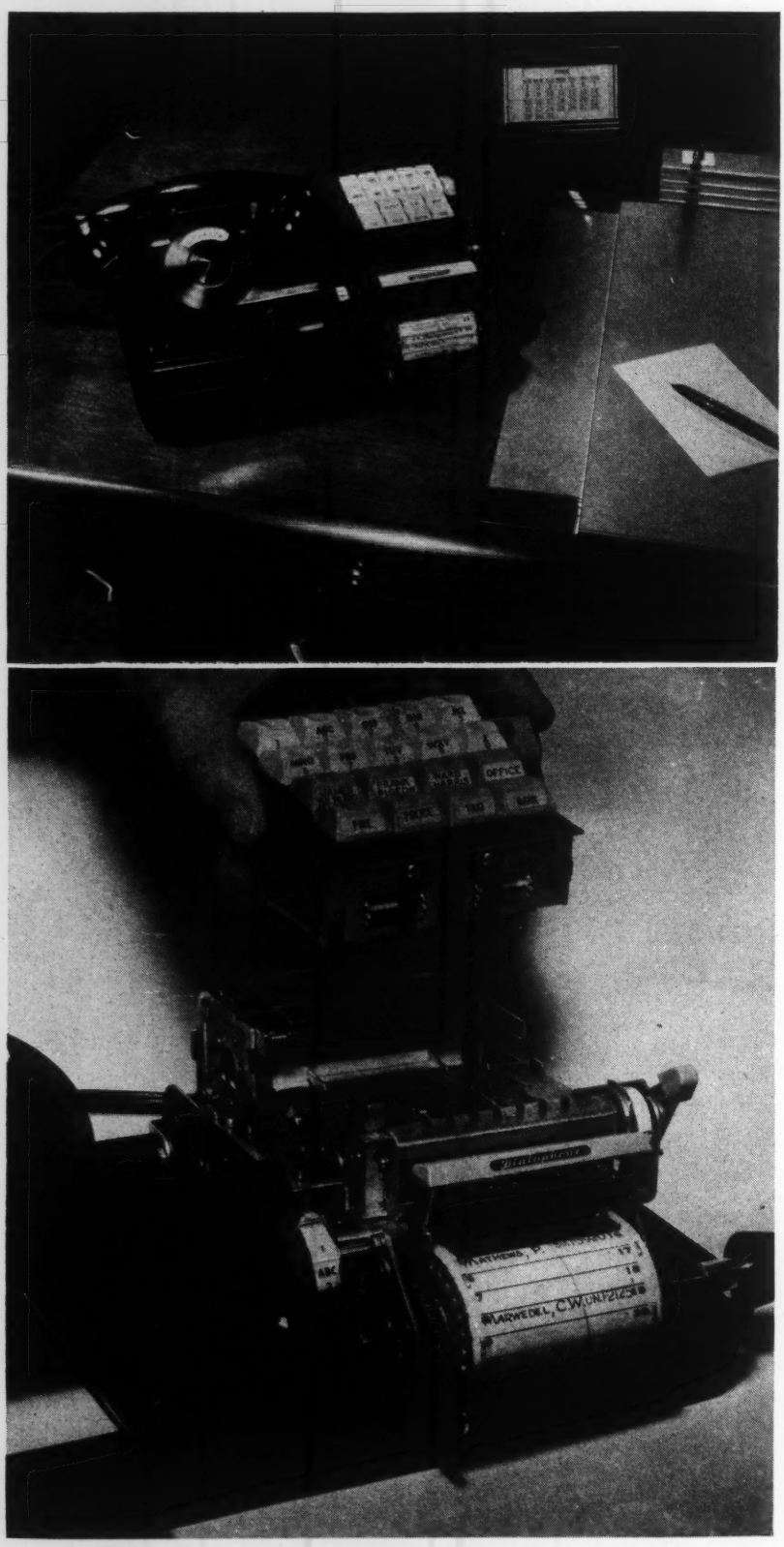
when unwound by the smoker.

After slitting, the banded wrapper is fed transversely under the cigar conveyor. When a cigar arrives at the wrapping station, it is pushed downward out of the holding fingers taking the wrapper along with it into the folding and sealing mechanism. In the folding and tucking operations, the wrapper is sealed by electrical heat elements. The heaters are plug-in connected to facilitate servicing and replacement.









Telephone Dialer Stores Numbers

AUTOMATIC dialing of conventional desk type telephones is performed by the compact device shown at left. Service cord plug-in at a convenient electrical outlet is the only installation requirement for operation of the unit. The regular dial control is actuated by a rubber finger in the dialing arm mechanism, which is hinged to permit manual dialing and easy exchange of telephones.

A built-in perforated tape "memory unit", left, below, enables the user to record over 500 call numbers in alphabetical sequence. Recorded listings are selected by means of a two-speed knob control and the self-dialing cycle is started by depressing a start bar after the dial tone is heard.

Eight frequently called (or emergency) numbers may be dialed by operation of single pushbuttons instead of indexing the tape roll. Non-recorded numbers can be set up on a keyboard for automatic dialing and subsequently erased by a single clearing key.

The Dialaphone, which is manufactured by James Kilburg Corp., also has a memo pad and pencil drawer built into the instrument base.

Electric
MOTOR DRIVES

By John W. Greve
Associate Editor, Machine Design

General Considerations 126
Standard vs. special motors—design trends—motor specification check list

Mechanical Features 132
Enclosures — frame sizes—mountings—bearings — insulation—built-in auxiliaries—accessories

Electrical Features 150
Motor theory—speed regulation—multispeeds—adjustable speeds—service factor—available motor types and sizes—single-phase motors—polyphase motors—dc motors—adjustable-voltage drives

General Application Factors 184
Load requirements—duty cycle—rms horsepower—stopping and reversing—motor acceleration—forced cooling—flywheel loads

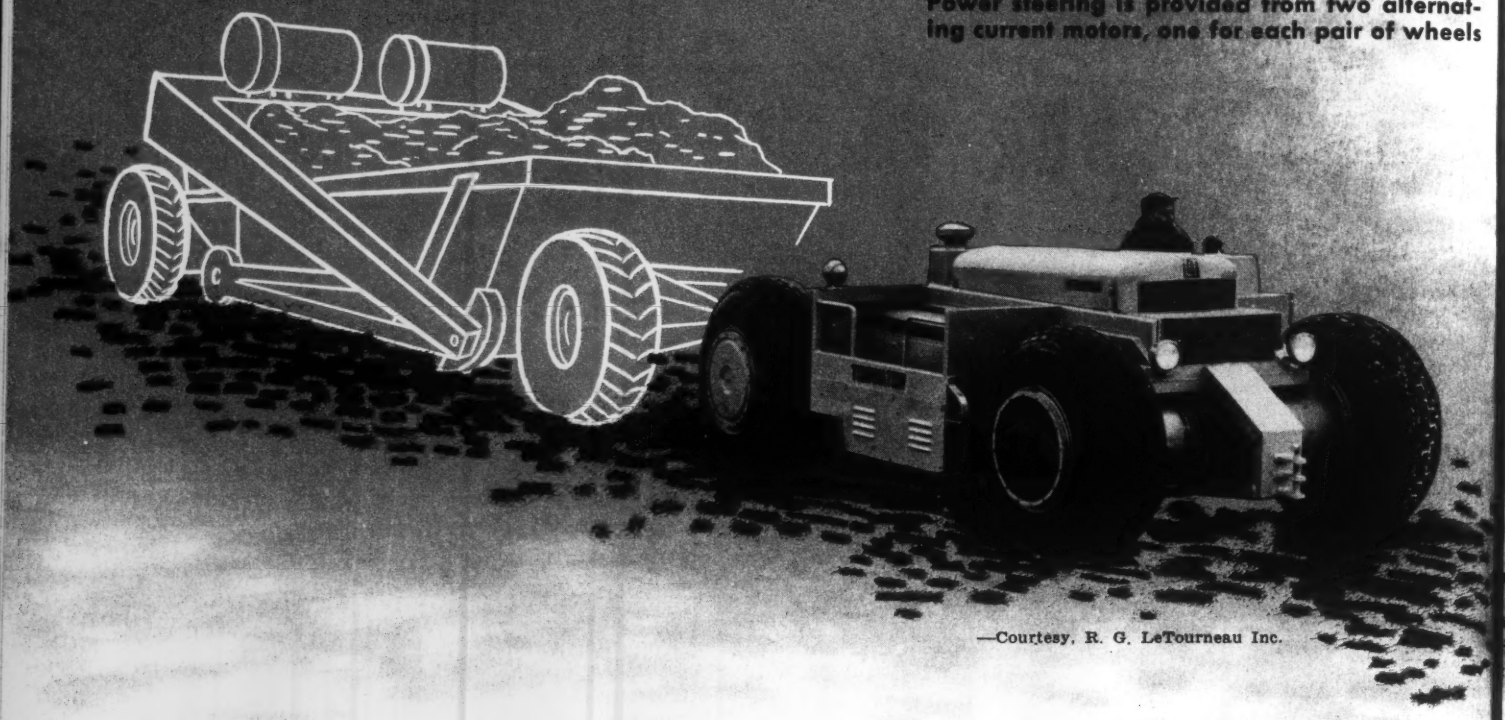


Fig. 1—Heavy-duty tractor propelled by electric motors. Each wheel is driven by individually mounted direct-current brakemotors. Power steering is provided from two alternating current motors, one for each pair of wheels

—Courtesy, R. G. LeTourneau Inc.

General Considerations.....

IN SELECTING and applying electric motors for machine drives, the designer usually has a multiplicity of choices that may seem bewildering. When these choices are divided into mechanical and electrical considerations and organized with respect to their features like an engineering problem, the best choice often becomes self-evident. Each mechanical feature has been designed for a particular type of application. Likewise, each type of electrical design has been developed to have basic characteristics. In this article, these features and characteristics will be reviewed and discussed with a view toward presenting considerations in a convenient form to aid the designer.

Electric motors probably have been the subject of more intensive development and more standardization of characteristics and dimensions than any other machine component. Yet, the variations seem limitless considering the possible combinations of mountings, bearings, enclosures, insulation, electrical characteristics, and built-in auxiliaries. One motor manufacturer who makes only four types of integral-horsepower motors lists over one million combinations with quoted prices as available on order. As a matter of fact, possible combinations of electrical, mechanical, and auxiliary features easily could account for more than one trillion different motors rated at a given horsepower.

Out of the seeming complications, there usually emerges one best motor for a particular application when all factors—including power supply, economy, drive requirements, service factor, operating conditions, and maintenance—are considered from an overall viewpoint. Even the problem of standard vs. special motors usually narrows down to a specific choice when the factors involved are considered from an engineering viewpoint.

By a standard motor is meant a motor that conforms to NEMA standards or is built as a stock item. These motors have many inherent advantages, chief among which are those accruing from mass-production methods. No additional development or research work is chargeable to the purchaser, no special shop orders with costly ramifications are involved, and no time is lost in development. If not available from stock in the quantities required, they are capable of being produced in a shorter time than that required for special designs. When built to NEMA standards,

comparable motors are obtainable from more than one source, a factor of particular importance in these days of shortages.

Special motors are built specifically on order and tailored to fit a particular application. Such tailoring may involve modifications of a standard motor or the development of a complete motor. Indicative of the extent to which special motors may be developed, the tractor in *Fig.* 1 utilizes tailored dc motors in each wheel for propulsion and ac motors for steering.

Typical of special mechanical features are built-in devices, mounting adaptations, changes in length and size of output shaft, and alterations in ratio of diameter to length of frame, *Fig.* 2. For many applications, they have definite and specific advantages. Electrical modifications involve chiefly such features as increased rating for short periods, modified speed-torque relations where more constant speeds over a wider load range is desired, higher rotor slip to reduce input current peak, etc.

With respect to making a decision between a standard or special motor, all the comparative considerations should be weighed carefully. In general, standard motors, *Fig.* 3, are less expensive. Another factor favoring standard motors involves maintenance on the machine by the user. The fact that these motors can be repaired or replaced readily is important to many users, particularly to manufacturers where down-time of a machine is costly in a production line.

Nevertheless special motors have distinct fields of application. Many manufacturers build only such motors. Where a standard motor cannot perform the functions required or where its size, shape or weight would be a handicap or impractical, the special motor has no rival. Portable-tool motors are excellent examples. The automotive-engine starting motor is another, inasmuch as a motor rated for other than extremely short periods would be much too large for practical application.

An interesting application involving special motors is shown in *Fig.* 4. This Ekstrom-Carlson moulder

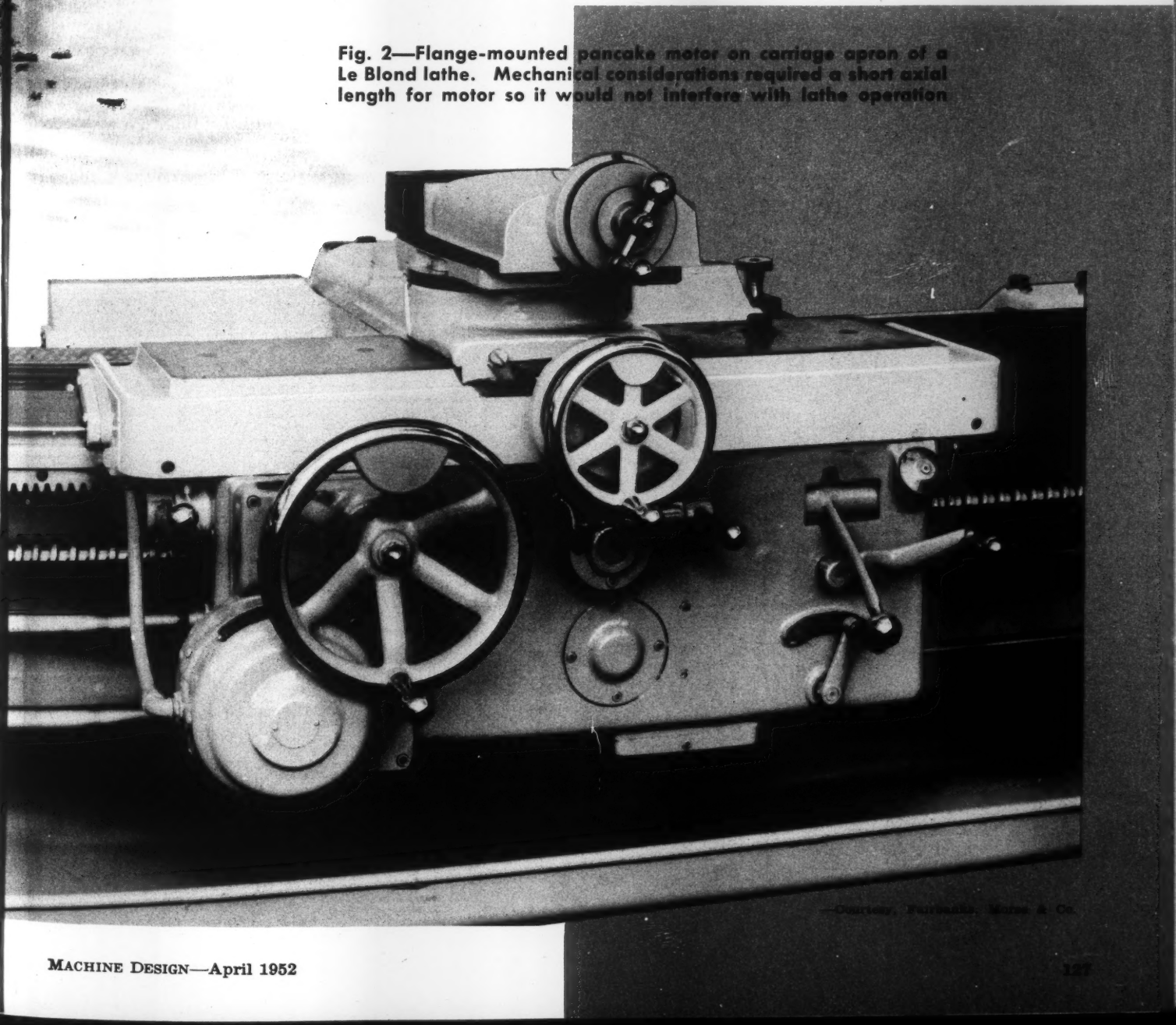
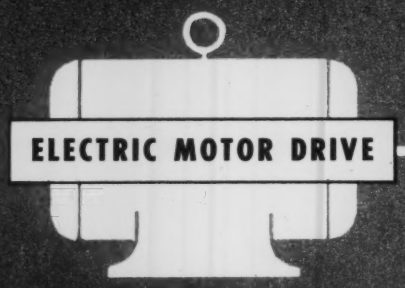


Fig. 2—Flange-mounted pancake motor on carriage apron of a Le Blond lathe. Mechanical considerations required a short axial length for motor so it would not interfere with lathe operation

—Courtesy, Reliance Motor & Co.

Table 1—Motor Selectio



ELECTRIC MOTOR DRIVE

CODES—STANDARDS

- AIEE
- NEMA
- AGMA
- ASA

Electrical Features

POWER SUPPLY

- DC
  - Rectified
  - CONSTANT
  - VOLTAGE
  - ADJUSTABLE
  - 32
  - 115
  - 230
  - Other
- AC
  - CYCLES
    - 25
    - 50
    - 60
    - 400
  - VOLTAGE
    - 110
    - 202
    - 220
    - 440
    - Other

MOTOR TYPE

- DC
  - Shunt
  - Series
  - Compound
  - Universal
- AC
  - POLYPHASE
    - Squirrel Cage
    - Wound Rotor
    - Synchronous
  - SINGLE-PHASE
    - Shaded Pole
      - Solid Coil
      - Wound Coil
    - Split-Phase
      - Permanent
      - Induction
    - Cap. Types
      - Cap.-start Ind.
      - Perm. Split
      - Two-Value
    - Rep. Types
      - Rep.-Start Ind.
      - Rep.-Ind.
      - Repulsion
    - Universal
    - Synchronous
      - True
      - Reluctance
      - Hysteresis
      - Permanent Magnet
      - Saga
  - No. Poles
    - 2
    - 4
    - 6
    - 8
    - 10
    - 12

CHARACTERISTICS

- SPEED
  - Regulation
  - Constant
  - Variable
  - Adjustable
  - Multispeed
  - Direction
  - Reversible
- HORSEPOWER
- TORQUE & CURRENT
  - Polyphase
    - Special
    - Design A
    - Design B
    - Design C
    - Design F
    - Design D
      - Slip
        - 5-8%
        - 8-13%
        - 15+%
  - Single-Phase
    - Special
    - Design L
    - Design M
- POWER FACTOR
- EFFICIENCY

DUTY CYCLE

- INTERMITTENT
- CONTINUOUS
- SHORT TIME

AMBIENT CONDITIONS

- TEMPERATURE
- ALTITUDE

Guide and Check List for Specification

ABS | UL | JIC | NE Code | Bureau of Mines | Army-Navy | Municipal

Mechanical Features

- **FRAME**
  - **ENCLOSURES**
    - **OPEN**
      - Skeleton
      - Nonprotected
      - Semiprotected
      - Protected
      - Dripproof
      - Splashproof
      - Extern. Vent.
      - Pipe-Ventilated
      - Sanitary
      - Water-cooled
      - Immersed
      - Lint-Free
    - **SHELL-TYPE**
      - Hermetic
    - **TOTALLY ENCLOSED**
      - Nonventilated
      - Fan-Cooled
      - Explosionproof
      - Dust-Explo'proof
      - Waterproof
      - Pipe-Ventilated
      - Submerged
  - **MOUNTINGS**
    - **HORIZONTAL or VERTICAL**
      - Foot
      - Bracket
      - Face
      - Flange
      - Shell
      - Resilient
      - Special
- **INSULATION**
  - CLASS A
  - CLASS B
  - CLASS H
- **BEARINGS**
  - **LUBRICATION**
    - Oil
    - Grease
  - **PROTECTION**
    - Sealed
    - Shielded
  - **TYPE**
    - Roller
    - Ball
    - Sleeve
  - **SINGLE**
  - **DOUBLE**
  - **THRUST**
- **SHAFT**
  - **EXTENSION**
    - Fastening
      - Flat
      - Keyway
      - Taper
      - Spline
      - Thread
      - Special
    - Single
    - Hollow
    - Double
    - Diameter
    - Length
      - Standard or Short
  - **MATERIAL**
    - Steel
      - Plated
    - Bronze
    - Stainless
    - Monel
    - Special
- **AUXILIARIES**
  - Governor
  - Clutch
  - Brake
  - Gearing
  - Thermal Protection
  - Speed Indicator
  - Plugging Switch
  - Transmission
  - Space Heater
- **ACCESSORIES**
  - Conduit Box
  - Lead Connections
  - Start Switch
  - Nameplate
- **MISCELLANEOUS**
  - Dynamic Balance
  - Paint
  - Quiet Operation

has sufficient capacity for various jobs requiring spindle-drive motors ranging from 5 to 25 horsepower. Regardless of the motor size, the frame size (diameter and mounting dimensions) is the same for each. Because the space occupied by the diameter of the motor is at a premium, the diameter of the smallest motor is used. For larger ratings the motors would have their frames extended axially to make "sausage" motors. This method has simplified the machining of the mounting brackets inasmuch as the same bracket fits all horsepower motors. In this way bulk has been reduced and a compact machine results for all sizes.

Instead of employing direct-drive high-cycle motors to develop the speed required of the cutter heads, the spindles are driven at selected speeds up to 7200 rpm by 3600 rpm motors through steel-core V-belts.

Undoubtedly, trends in design are toward using higher motor speeds and higher permissible operating temperatures. Both factors permit the design of more compact machines. These trends are of more than passing interest to machine designers because they will facilitate application in confined locations and minimize the problems of heat dissipation from the motor. For applications requiring lower speeds, gearmotors provide a compact unit. Reversing duty motors permit the elimination of mechanical clutch and reversing systems. From the viewpoint of conservation of critical materials alone these trends appear significant.

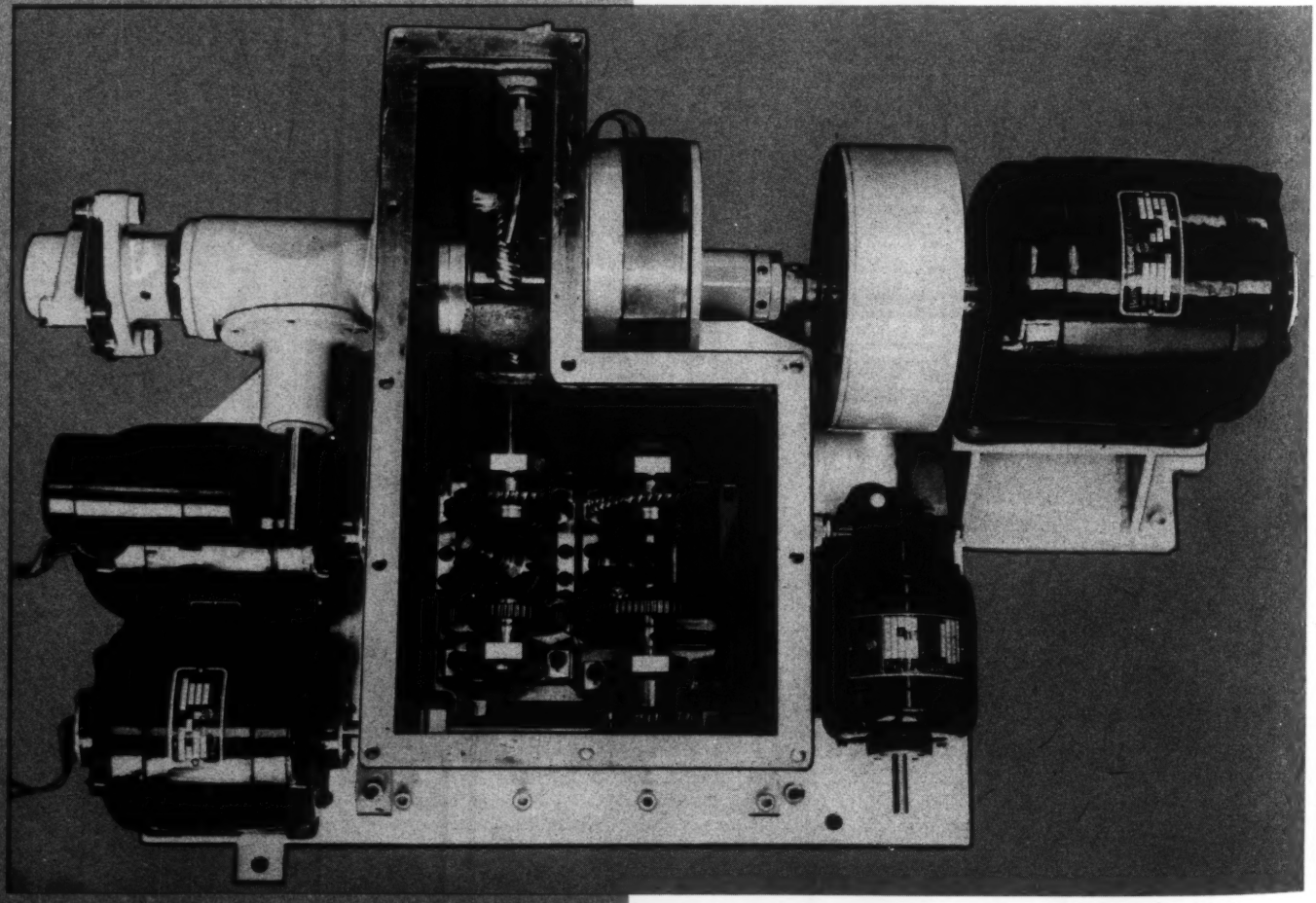
With the development of production machines requiring increased horsepower, the motor space problem has become more significant. Generally, a machine of relatively the same physical size today requires 50 per cent more horsepower than formerly.

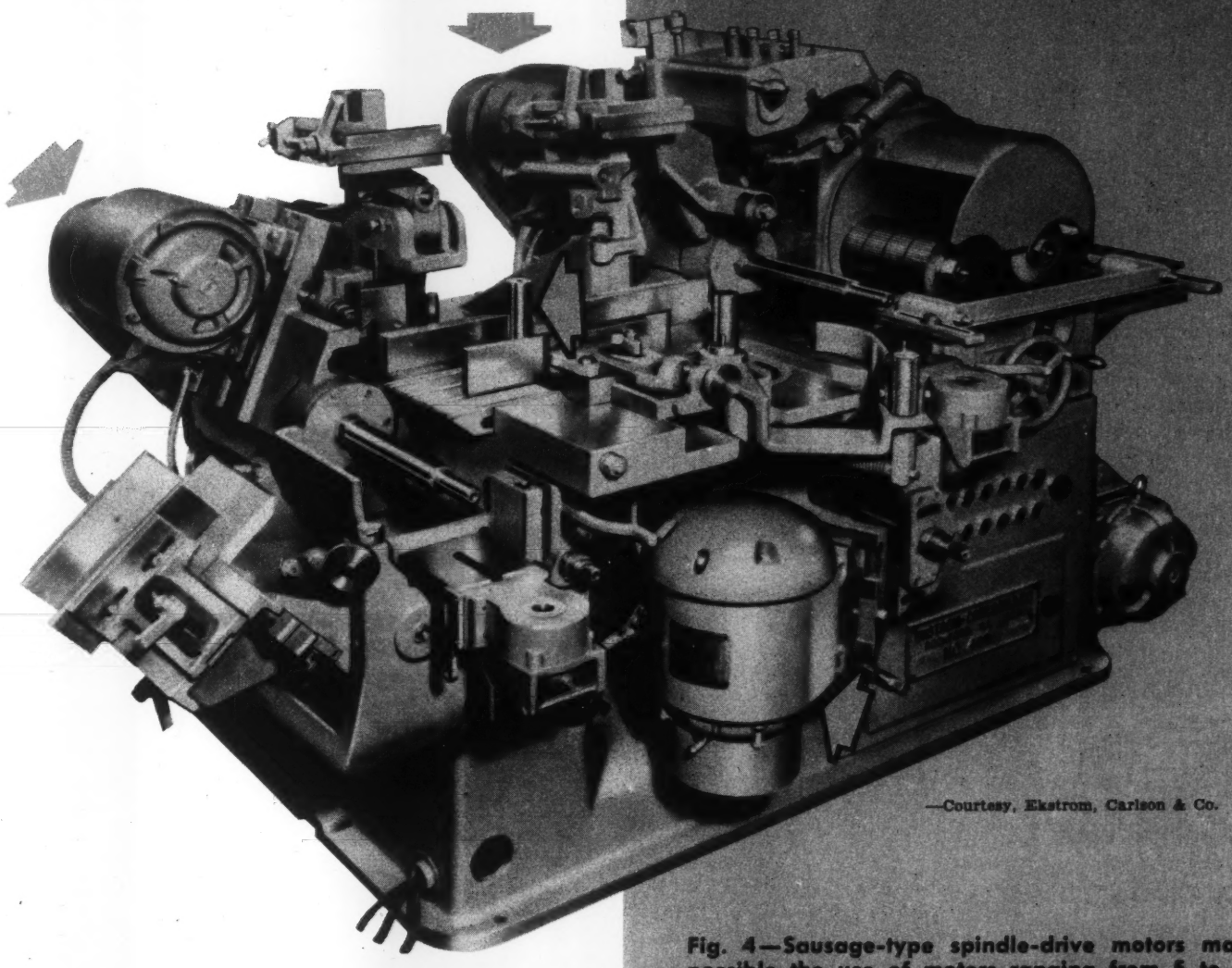
With respect to standard industrial drives it has been anticipated that motors may be developed and designed in frames of two, or possibly three, sizes smaller than currently standard. This means that a 5-hp motor may be the size of a present 2 or 1½-hp unit, a 7½-hp motor may become the size of a 3 or 2-hp drive, and a 40-hp motor may reduce in size to a 20 or 15-hp frame. This progress could be anticipated from the fact that, during the past 50 years, the horsepower rating for the same frame size has increased from 7½ to 40 horsepower, an increase of over five times in power output.

Another consideration toward compactness in design involves the utilization of polyphase motors. Although these motors have always been standard their advantages with respect to compactness often have been overlooked even where polyphase power is avail-

Fig. 3—Standard foot-mounted motors operating the right ascension drive on the Schmidt 48-inch refracting telescope on Mt. Palomar

—Courtesy, Bodine Electric Co.





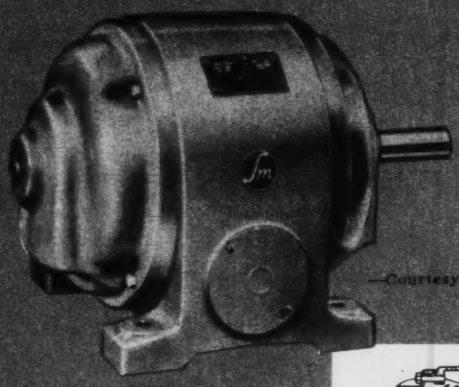
—Courtesy, Ekstrom, Carlson & Co.

Fig. 4—Sausage-type spindle-drive motors make possible the use of motors ranging from 5 to 25 horsepower with the mounting dimensions of 5-horsepower motors (shown), simplifying construction and providing a more compact design. Reliance motors drive the four spindles through V-belts

able. This has been particularly true in the application of fractional-horsepower motors. In aircraft having polyphase power, single-phase motors are sometimes employed for auxiliaries. Presumably the designer had in mind reducing the number of leads without perhaps considering the weight saving of a polyphase motor and its other operating advantages. In some industrial plants, however, all motors on production machines which are ¼-horsepower or larger must be 3-phase motors. Generally, a polyphase motor develops 40 to 50 per cent more power than a single-phase motor for a given frame size. In addition polyphase motors require no starting auxiliaries, develop better starting characteristics and have better efficiency.

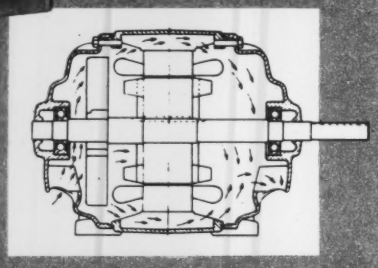
Service and maintenance are important considerations not only when the decision of standard vs. special motors is being made but also when the installation is laid-out. As in all good design, trouble-free service and ease of maintenance should be planned. This evaluation includes the quality and type of motor that is being selected as well as the manner in which the motor is applied. If, for instance, an open-type motor is considered, provisions must be made so that harmful material or objects cannot enter the motor. Its location and intended environment during use should not contribute to shortening the life or unduly increasing maintenance. To provide for maintenance or possible replacement, however, the motor drive should be placed in an accessible location, protected as much as possible and provided with adequate ventilation.

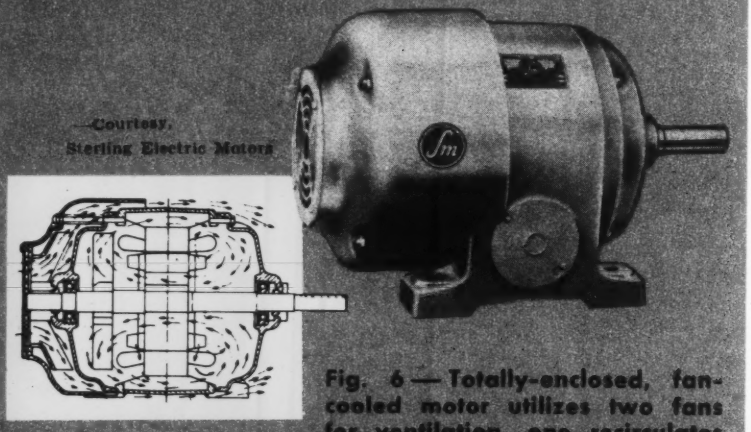
General factors involved in motor selection are shown in the organizational chart, TABLE 1, showing the family-tree relationships of each feature. This chart may prove useful as a check-list in reviewing motor specifications or in considering the motor features desired for a new application.



—Courtesy, Sterling Electric Motors

Fig. 5—Drippproof motor protected for use in damp places, utilizes a fan for ventilation, blowing air over the rotor and field windings as shown in the sectional view





—Courtesy, Sterling Electric Motors

Fig. 6 — Totally-enclosed, fan-cooled motor utilizes two fans for ventilation, one recirculates air inside the motor and a second, being external, blows air over the frame to dissipate the heat conducted through the frame as shown in the sectional view

Mechanical Features...

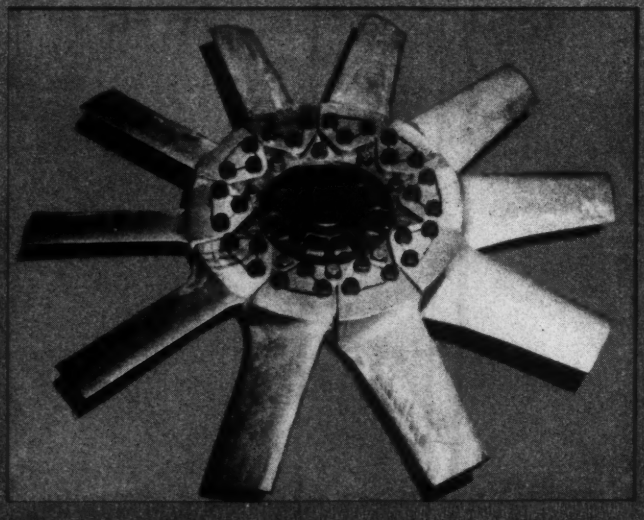
IN A DRIVE, motor selection involves two major groups of considerations—mechanical and electrical. Usually the type of motor enclosure needed and method of mounting desired are early considerations. Then, knowing the horsepower and speed requirements, the size and dimensions of the motor are fixed for standard motors. When the machine drive shaft operates at low speed, high-speed motors with built-in gear reductions in the form of a gearmotor are usually advantageous. For such cases, the altered size and shape of the gearmotor, which is not necessarily larger physically, must be considered.

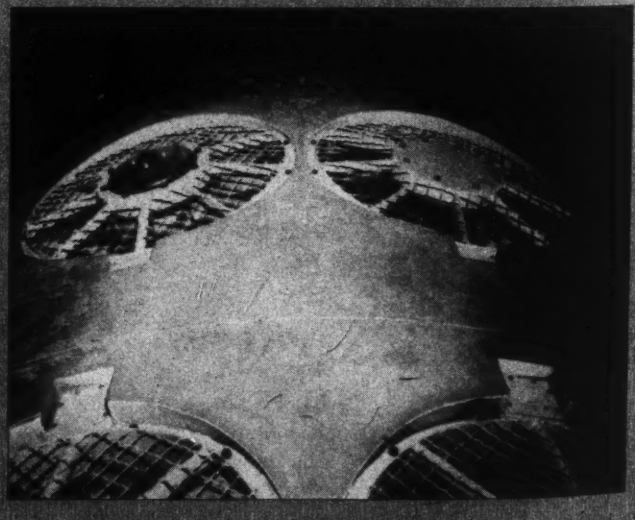
According to the type of power supply available, the electrical design is then determined, based on speed-torque relationships over the operating load range, the starting torque, the starting current, the motor efficiency, and power factor. The latter two are unimportant for most applications but are considered in special cases or where increased efficiency may minimize a heat dissipation problem.

Motor sizes are grouped by NEMA into two subdivisions, fractional and integral. A fractional-horsepower motor is built in a frame smaller than a comparable motor having a continuous rating of one horsepower, open construction, at 1700-1800 rpm. All larger motors are classified as integral-horsepower motors. As an example, a one-horsepower, 3500-rpm motor is in the fractional-horsepower group. Inasmuch as the standards do not list fractional-horsepower motors smaller than 1/20-horsepower, motors

Fig. 7—Pancake motors with fan blades bolted on armature obviate shaft extension, saving valuable space for diesel-engine fans mounted in housing

—Courtesy, Fairbanks, Morse & Co.





below this rating are generally referred to as subfractional and extremely small sizes are popularly called "miniature" or "flea-power" motors.

Classification according to application embraces three subdivisions: general purpose, definite purpose and special purpose.

1. *General-purpose motors* are built in open frames for a continuous 40 C temperature rise in standard ratings having standard operating characteristics and are designed for regular service without restriction to a particular application requirement
2. *Definite-purpose motors* are made in standard ratings with standard characteristics or construction but are for service conditions other than usual or for a particular type of application
3. *Special-purpose motors* have special operating characteristics or mechanical construction and are designed for a particular application not included in either the general-purpose or definite-purpose categories.

Enclosures: Selection of motor enclosures, or type of frame design, is dictated by operating conditions. Generally recognized types of enclosures, including NEMA definitions, are classified in the following:

A. **Open Motors** have ventilating openings to permit the passage of air over the windings. Specific types of open-frame motors include:

1. *Skeleton motors* have no frame, so to speak, field coils are not protected and bearing brackets are usually mounted on the stator
2. *Semiprotected motors* have part of the openings covered, such as those in the top half to prevent falling objects from entering
3. *Protected motors* have each opening limited in size and shape, generally not to exceed ½ square inch
4. *Dripproof motors* prevent drops of liquid or solid particles from entering which fall at an angle of 15 degrees or less from the vertical or which run along a surface
5. *Dripproof fully-protected motors* combine the features of the two preceding types
6. *Splashproof motors* have openings so protected that drops of liquid falling at an angle not greater than 100 degrees from vertical cannot enter the motor either directly or by running along a surface
7. *Externally-ventilated motors* are any of the preceding open types but ventilated by a separate motor-driven blower
8. *Pipe-ventilated motors* have all openings for ventilation arranged for duct or pipe connections. This type is sometimes called a separately or forced ventilated motor
9. *Sanitary motors* are splashproof motors designed to meet sanitary standards of food and dairy associations. Motors have all external surfaces and contours smoothly rounded and finished. There are no pockets, cracks or crevices which might collect dirt and bacteria
10. *Lint-free motors* have ventilating passages sufficiently large and smooth to minimize deposits of air-borne particles
11. *Water-cooled motors* have provisions for circulating water through channels surrounding the stator to increase motor capacity
12. *Immersed motors* are capable of operating immersed in a liquid. Motor parts and insulation must not be subject to attack or deterioration from fluid. Rotors are designed to minimize turbulence and drag from fluid.

B. **Totally-Enclosed Motors** prevent the exchange of air between the inside and outside of the motor but are not air-tight. Six types of these motors have been classified as standard and are:

1. *Nonventilated motors* have no provisions for external cooling other than fins or radiating surfaces on the frame
2. *Fan-cooled motors* have integral fans for external cooling of the enclosing parts
3. *Explosionproof motors* withstand explosion of vapor within the motor and prevent ignition, from this explosion, of gas or vapor outside the motor
4. *Dust-explosionproof motors* are constructed so that they will not ignite or explode an ambient atmosphere of dust or dust on or around the motor
5. *Waterproof motors* exclude water applied in the form of a stream from a hose. Leakage around the shaft is prevented from entering the oil reservoir and is automatically drained
6. *Pipe-ventilated motors* have provisions for inlet and outlet ducts or pipes to admit and discharge ventilating air.

C. **Shell-Type Motors** consist of stator and rotor without shaft, end shields, bearings, or frame. Outside stator diameter is machined to close tolerances.

D. **Hermetic Motor** is a shell-type motor designed for installation in refrigerant units of the hermetically sealed type.

For the majority of applications, standard open-frame motors are protected sufficiently. Often, however, additional protection is justified in view of reduced maintenance and increased reliability of operation. Some materials, like dust, are not injurious to the motor windings, but unless frequently cleaned out, may reduce ventilation and cause excessively high motor temperatures. For such conditions, motors are designed with wide clearances and smooth surfaces in the ventilating passages to provide free flow of dust and lint or to facilitate blowing out the dirt if it should collect. Other materials such as abrasives and chemicals that are injurious should be excluded from the motor by a totally-enclosed frame to reduce motor maintenance and increase service life.

Dripproof and splashproof motors, *Fig.* 5, are employed primarily where excessive moisture is present. Splashproof motors are especially useful where a hose may be used for cleaning. They are used extensively in paper mills, textile mills, chemical plants, packing houses, etc. Although such motors are protected against direct action of water, ventilating air still passes over the coils and foreign materials may still collect on the windings, requiring maintenance to prevent overheating.

Complete enclosure, in the form of a totally-enclosed motor, is ideal from the standpoint of preventing the collection of dirt inside the motor. Nonventilated motors are economical only in small horsepower ratings if desired for continuous duty. They have been applied widely in production machines for auxiliary drives but, as a rule, are limited economically to sizes under 3 horsepower. For larger sizes, the fan-cooled types are advantageous and more economical. When used for intermittent duty, such as positioning, adjusting and valve operating, nonventilated motors

are satisfactory for any size because they are selected on the basis of torque rather than heat developed. When the operating time is short enough, heating and ventilating are of little importance.

High maintenance of open-motor industrial drives was probably responsible for the development of the fan-cooled totally-enclosed motor. Applied as readily as open types, they require the same mounting dimensions, except for a few cases. In these motors, *Fig.* 6, the internal air is circulated by the rotor, conducting the heat to the frame where an externally mounted fan dissipates the heat from the frame exterior by blowing air over it.

Pipe-ventilated motors, employing forced ventilation produced by an exterior blower and duct system, have the most effective method of cooling but are relatively complicated and expensive to install. These factors limit their use to large installations. Except for the hazardous locations no return or exhaust ducts are required, the air being exhausted to the atmosphere from the motor. For direct-current motors operating on variable-voltage speed control, forced ventilation allows full-torque operation for continued periods, when operating at speeds as low as 10 per cent full speed.

Although application conditions determine the type of motor enclosure needed for satisfactory performance, the choice of an open type or fully enclosed motor is often a matter of cost. As an indication of approximate relative costs the following tabulation compares four basic types:

Enclosure	Cost (%)
Open Protected	100
Splashproof	107
Enclosed, Fan-cooled	138
Explosionproof	162

Explosive Atmospheres: Hazardous locations requiring totally-enclosed motors of the explosionproof types are defined in the National Electrical Code and are classified as follows:

CLASS I

GROUP A: Atmospheres containing acetylene

GROUP B: Atmospheres containing hydrogen, or gases or vapors of equivalent hazard such as manufactured gas

GROUP C: Atmospheres containing ethyl ether vapor

GROUP D: Atmospheres containing gasoline, petroleum, naphtha, alcohols, acetone, lacquer solvent vapors, and natural gas

CLASS II

GROUP E: Atmospheres containing metal dust

GROUP F: Atmospheres containing carbon black, coal or coke dust

GROUP G: Atmospheres containing grain dust

CLASS III

Locations containing easily ignitable fibers or flyings but with only a small amount in suspension in the air.

For these locations, explosionproof enclosures fulfill the requirements for Class I hazardous locations and the dust-explosionproof enclosures are designed for Class II groups.

Frame Sizes: Physical dimensions of an electric motor have optimum values of diameter and length ratios. For a given horsepower, speed and duty cycle, these values become fixed if there are no other factors involved. Effective use of iron and copper in the electrical circuit, considering air-gap characteristics, determines these proportions. Generally, the NEMA standard dimensions have the objective of following these proportions. Inasmuch as frame diameter-to-length ratios roughly approximate the electrically active component ratios, it is interesting to note that this ratio is 0.65 ± 0.05 based on maximum dimensions of commercially standard motors.

Frequently other considerations are involved, however, necessitating variations in these relations. For instance, the shape of an enclosure in which a motor must be confined may indicate that a special shape is justified. Portable tools often utilize elongated motors to produce a shape more suited to use. Mechanical requirements of a drive, such as rapid reversal, might indicate that an elongated or sausage-type motor has advantages due to the reduced inertia of the rotor. At the other extreme of shape, the pancake motor may be advantageous where axial length is restricted, where moving multiple heads require close coupling, or where the added flywheel effect may be advantageous in reducing speed variations resulting from high-load peaks of short duration in the duty cycle. In extreme shapes, however, utilization of active material is sacrificed to gain the desired additional features.

Indicative of the space-saving possibilities (lengthwise) of pancake motors is the fan installation on a diesel engine for a locomotive shown in *Fig.* 7. The fans are rated 16 horsepower at 1640 rpm, using 3-phase, 113-cycle, 450-volt power. With a pancake motor of the axial air-gap type, it is possible to bolt the blades directly to the rotor as shown in the illustration, eliminating the shaft extension. Overall length of the motor is 11¾ inches which is about 1/3 that of a conventional unit. Weight of the fan-motor is 232 pounds and the unit is open to the weather, being mounted on top of the locomotive. The fan itself has 10 blades with a diameter of 44 inches and a capacity of 31,000 cfm.

Standard dimensions of motor frames for foot mounting involve mounting dimensions of the foot, height of the shaft, length and diameter of shaft extension, and shaft keyway dimensions as shown in TABLE 2. For draftsman's use the maximum overall dimensions for these motor frame numbers, compiled by Ford-JIC from commercial motors are listed in TABLE 3. Letter designations shown on motor drawings as dimensions are defined in TABLE 4.

For fractional-horsepower motors the frame number is 16 times the shaft height, or *D* dimension, in inches, as shown in TABLE 2 for the first four frames. Suffix letters following the frame number are used to denote variations such as *C* for face mounting, *G* for gasoline pump motor, *L* for washing machine motor, *M* and *N* for oil burner motors, *Y* for special mounting dimensions, and *Z* for standard except shaft extension.

For integral-horsepower motors, the first two digits of the frame number are equal to 4 times the shaft height, or *D* dimension, inches. The third digit is associated with the mounting hole distance from the

Table 2—Standard Dimensions for Foot-Mounted Motors§

(Dimensions are defined by drawing and TABLE 4)

Motor Frame (No.)	Shaft: Height from Foot‡ D (in.)	Shaft: Diameter U (in.)	Shaft: Length from Shoulder V (min) (in.)	Shaft: Extension* N-W (in.)	Shaft: Key Dimensions (in.)	Mounting Feet: Hole to Shaft† BA (in.)	Mounting Feet: Feet Width A (max) (in.)	Mounting Feet: Feet Length B (max) (in.)	Mounting Feet: Hole to Centerline Width E (in.)	Mounting Feet: Hole to Centerline Length F (in.)	Mounting Feet: Hole Diameter H (1/32-in.
42	2⅝	⅜	1⅛	1⅛	$\frac{3}{64}$ Flat	2$\frac{1}{16}$	..	..	1¾	$\frac{37}{64}$	9 (Slot)
48	3	½	1½	1½	.. .. ..	2½	..	..	2⅛	1⅜	9 (Slot)
56	3½	⅝	1⅞	1⅞	$\frac{3}{16} \times \frac{3}{16} \times 1\frac{3}{8}$	2¾	..	..	2$\frac{7}{16}$	1½	11 (Slot)
66	4⅛	¾	2	2¼	$\frac{3}{16} \times \frac{3}{16} \times 1\frac{7}{8}$	3⅛	..	..	2$\frac{15}{16}$	2½	13 (Slot)
203	5††	¾	2	2¼	$\frac{3}{16} \times \frac{3}{16} \times 1\frac{3}{8}$	3⅛	10	7½	4	2¾	13
204	5††	¾	2	2¼	$\frac{3}{16} \times \frac{3}{16} \times 1\frac{3}{8}$	3⅛	10	8½	4	3¼	13
224	5½	1	2¾	3	¼ × ¼ × 2	3½	11	8¾	4½	3⅜	13
225	5½	1	2¾	3	¼ × ¼ × 2	3½	11	9½	4½	3¾	13
254	6¼	1⅛	3⅛	3⅜	¼ × ¼ × 2⅜	4¼	12½	10¾	5	4⅛	17
284	7	1¼	3½	3¾	¼ × ¼ × 2¾	4¾	14	12½	5½	4¾	17
324	8	1⅝	4⅝	4⅞	⅜ × ⅜ × 3¾	5¼	16	14	6¼	5¼	21
326	8	1⅝	4⅝	4⅞	⅜ × ⅜ × 3¾	5¼	16	15½	6¼	6	21
364	9	1⅞	5⅜	5⅝	½ × ½ × 4¼	5⅞	18	15¼	7	5⅝	21
364S	9	1⅝	3	3¼	⅜ × ⅜ × 1⅞	5⅞	18	15¼	7	5⅝	21
365	9	1⅞	5⅜	5⅝	½ × ½ × 4¼	5⅞	18	16¼	7	6⅛	21
365S	9	1⅝	3	3¼	⅜ × ⅜ × 1⅞	5⅞	18	16¼	7	6⅛	21
404	10	2⅛	6⅛	6⅜	½ × ½ × 5	6⅝	20	16¼	8	6⅛	26
404S	10	1⅞	3½	3¾	½ × ½ × 2	6⅝	20	16¼	8	6⅛	26
405	10	2⅛	6⅛	6⅜	½ × ½ × 5	6⅝	20	17¾	8	6⅞	26
405S	10	1⅞	3½	3¾	½ × ½ × 2	6⅝	20	17¾	8	6⅞	26
444	11	2⅜	6⅞	7⅛	⅝ × ⅝ × 5½	7½	22	18½	9	7¼	26
444S	11	2⅛	4	4¼	½ × ½ × 2¾	7½	22	18½	9	7¼	26
445	11	2⅜	6⅞	7⅛	⅝ × ⅝ × 5½	7½	22	20½	9	8¼	26
445S	11	2⅛	4	4¼	½ × ½ × 2¾	7½	22	20½	9	8¼	26
504U	12½	2⅞	8⅜	8⅝	¾ × ¾ × 7¼	8½	25	21	10	8	30
504S	12½	2⅛	4	4¼	½ × ½ × 2¾	8½	25	21	10	8	30
505	12½	2⅞	8⅜	8⅝	¾ × ¾ × 7¼	8½	25	23	10	9	30
505S	12½	2⅛	4	4¼	½ × ½ × 2¾	8½	25	23	10	9	30

§ Based on NEMA Standard MG1-3.2.
* Length of shaft extension from shoulder to end of shaft.
† Horizontal distance from centerline of nearest mounting hole to shaft shoulder.
‡ When exact dimensions are required, shims up to $\frac{1}{32}$-inch may be required for frames up to 326. Larger frames may require shims up to $\frac{1}{16}$-inch.

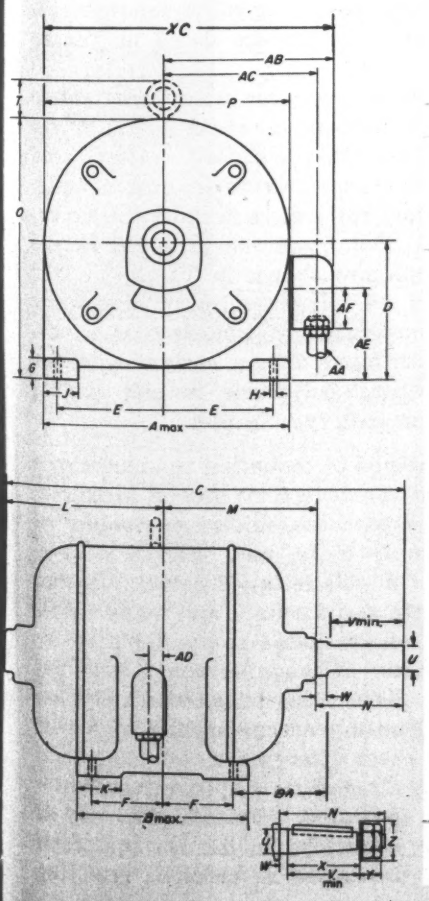


Table 3—Maximum Outline Dimensions of A-C Motors*

(Dimensions are defined in drawing and TABLE 4)

Motor Frame (No.)	Overall: Length C (max) (in.)	Overall: Width XC (max) (in.)	Frame: Height O (max) (in.)	Frame: Width P (max) (in.)	Eye Bolt Height T (max) (in.)	Feet: Length K (max) (in.)	Feet: CL to Housing End M (max) (in.)	Conduit Box: Width from CL AB (max) (in.)	Conduit Box: Entrance from Frame CL: Width AC (max) (in.)	Conduit Box: Entrance from Frame CL: Below AF (max) (in.)
203	15	....	....	....	...	...	....	....	....	...
204	16½	12⅞	9⅞	9¾	...	1⅞	6⅜	7⅞	6½	1¾
224	19½	14⅝	11½	12	2⅝	2	7	8⅝	7⅜	1⅝
225	20¼	14⅝	11½	12	2⅝	2	7¼	8⅝	7⅜	1⅝
254	23	16½	12½	12⅝	2⅝	2½	8¼	10¼	8⅜	2⅛
284	26⅛	18⅝	14⅜	14⅝	3	2½	9⅜	11⅛	9¼	2⅛
324	29⅜	21⅛	16⅜	16⅝	3⅝	3½	10⅜	12⅞	10½	3⅛
326	31⅛	21⅛	16⅜	16⅝	3⅝	3½	11⅛	12⅞	10½	3⅛
364	32¾	23⅛	18¼	18⅜	3⅝	3½	11⅜	14	11⅝	3⅛
364S	30⅜	23⅛	18¼	18⅜	3⅝	3½	11⅝	14	11⅝	3⅛
365	33¾	23⅛	18¼	18⅜	3⅝	3½	11⅞	14	11⅝	3⅛
365S	31⅜	23⅛	18¼	18⅜	3⅝	3½	11⅞	14	11⅝	3⅛
404	36	25⅜	20⅜	20⅝	3⅝	3½	12⅝	15⅛	12¾	3⅛
404S	33⅜	25⅜	20⅜	20⅝	3⅝	3½	12⅝	15⅛	12¾	3⅛
405	37½	25⅜	20⅜	20⅝	3⅝	3½	13⅜	15⅛	12¾	3⅛
405S	34⅞	25⅜	20⅜	20⅝	3⅝	3½	13⅜	15⅛	12¾	3⅛
444	41	27⅛	22	21⅞	4¼	3⅞	14⅝	16⅛	13¾	3⅛
444S	38⅛	27⅛	22	21⅞	4¼	3⅞	14⅝	16⅛	13¾	3⅛
445	43	27⅛	22	21⅞	4¼	3⅞	15⅝	16⅛	13¾	3⅛
445S	40⅛	27⅛	22	21⅞	4¼	3⅞	15⅝	16⅛	13¾	3⅛
504U	45½	30½	25¼	25½	4¼	6⅝	16⅜	17¾	15⅝	4⅛
504S	41⅛	30½	25¼	25½	4¼	6⅝	16⅜	17¾	15⅝	4⅛
505	48¼	30½	25¼	25½	4¼	6⅝	17⅜	17¾	15⅝	4⅛
505S	43⅞	30½	25¼	25½	4¼	6⅝	17⅜	17¾	15⅝	4⅛

* Based on Ford JIC Standards.

Table 4—Standard Letter Designations for Motor Dimensions

(from NEMA Standards)

Letters	Dimensions Indicated
A (max)	Overall dimension across feet of horizontal machine (end view)
B (max)	Overall dimension across feet of horizontal machine (side view)
C	Overall length of machine less pulley (for single shaft extension)
D	Centerline of shaft to bottom of feet
E	Centerline of machine to centerline of mounting holes in feet (end view)
F	Centerline of base or feet of horizontal machine to centerline of mounting holes in feet (side view)
G	Thickness of feet of machine
H	Diameter of holes or width of slot in feet of machine
J	Width of end of feet of horizontal or vertical machine
K	Length of feet of horizontal or vertical machine (side view)
L	Centerline of base or feet of horizontal machine to end of housing (end opposite the shaft)
M	Centerline of base or feet of horizontal machine to end of housing (shaft end)
N	Length of shaft from end of housing to end of shaft
O	Top of horizontal machine to bottom of feet
P	Diameter of vertical or horizontal machine
S	Centerline of base or feet of horizontal machine to centerline of pulley
T	Height of eye bolt above top of machine
U	Diameter of shaft extension (for tapered shaft, largest diameter of taper)
V (min)	Length of shaft available for coupling, pinion or pulley hub
W	For straight shaft, end of housing to end of shoulder; for tapered shaft, end of housing to beginning of taper
X	Length of hub of pinion when using full length of taper
Y	Distance from end of shaft to outer end of taper
Z	Width across corners of nut or diameter of washer, on tapered shaft
AA	Diameter of conduit (pipe size)
AB	Centerline of machine to extreme outside part of conduit box (end view)
AC	Centerline of machine to centerline of hole *AA* for conduit entrance (end view)
AD	Centerline of machine to centerline of conduit box inlet (side view)
AE	Centerline of conduit box inlet to bottom of feet (horizontal)
AF	Centerline of conduit box inlet to conduit entrance
AG	Mounting surface of face, flange or base of vertical machine to opposite end of machine (side view)
AH	Distance from mounting surface of face or flange to end of shaft
AJ	Diameter of bolt circle in face or flange or in base of vertical machine
AK	Diameter of male or female pilot on face or flange or on base of vertical machine
BA	Centerline of mounting hole in the nearest foot to the shoulder on shaft. Equal to $M + W - F$ (Not used on machines with tapered shafts)
BB	Depth of male or female pilot of face or flange or base of vertical machine
BC	Distance from mounting surface of face or flange or base of vertical machine to shoulder on shaft
BD (max)	Outside diameter of face or flange, or base of vertical machine
BE	Thickness of flange, or base of vertical machine
BF	Diameter of mounting holes in flange, or base of vertical machine
BG	Centerline of base or feet of horizontal machine to mounting surface of face or flange
BH	Outside diameter of core or shell (side view)
BJ (max)	Overall length of coils (side view)
BK (max)	Distance from centerline of stator to lead end of coils
BL (max)	Diameter over coils (*BL* = 2 times max radius)
BM	Overall length of stator shell
BN	Diameter of stator bore
BO	Length of rotor at bore
BP (max)	Length of rotor over fans
BR	Diameter of finished surface or collar at ends of rotor
BU	Angle between centerline of conduit box inlet and centerline of motor (end view)
BV	Centerline of conduit box inlet to mounting surface of face or flange.
BW (min)	Inside clearance of rotor fan for shell-type motor
XC	Overall width of motor, including conduit box (from Ford JIC Standards, not included in NEMA Standards)

base centerline (side view) shown as dimension *F* in TABLE 2. This third digit, however, does not correspond exactly with the *F* dimension in inches. Suffix letters following the frame number denote variations such as *C* for face mounting, *D* for flange mounting, *P* and *PH* for hollow-shaft vertical motors, *S* for short shaft, *U* for different shaft extension diameter, *V* for vertical mounting, *Y* for special mounting, and *Z* for standard except shaft extension for belt drive.

Frame sizes listed in TABLE 2 are assigned to motors with respect to enclosure, horsepower, and speed characteristics. Standard single-phase motors for 60-cycle, 115-230 volt power are shown in TABLE 5, for both vertical and horizontal mounting. From this the mounting dimensions as well as shaft position and extension may be determined. The maximum frame dimensions listed in TABLE 3, based on a number of manufacturer's motors, give an indication of the space required.

In providing space and mounting for a motor, many machine manufacturers design for one size larger motor than that supplied for the drive. This is done so that the user may, if need be, install a larger motor to facilitate maintenance or to meet unanticipated production needs. In fact many users specify these additional provisions for their production machines. The standard frames assigned to motor types and ratings are particularly useful to the designer by providing motor mounting dimensions. No horsepower and speed ratings have been assigned to fractional-horsepower motors, but the integral-horsepower ratings assigned to motor frames are listed in TABLES 5, 6 and 7.

In TABLE 6 are frame sizes for polyphase motors including squirrel-cage motors (Designs *A* and *B*) for open, splashproof and totally-enclosed motors; and wound-rotor general-purpose motors in open frames.

Direct-current motor frame sizes for integral-horsepower ratings up to 25 horsepower in speed ranges from 3500 to 690 rpm are shown in TABLE 7. The frame sizes tabulated are for general-purpose motors, open frames, 40 C temperature rise, horizontal or vertical mounting. Additional frame assignments for standard motors include polyphase motors having multispeed windings in open type frames.

Mounting: The method of mounting the motor to a machine is worthy of the designer's special attention. Good appearance, compactness, minimum number of parts, reduced assembly costs, and ease of maintenance are features of a well-designed drive. Various types of mountings are standardized and many variations and modifications are listed as available by individual manufacturers. Because he has a wide variety from which to choose, the designer usually has only to select the mounting arrangement which best meets his needs. In cases where no motor has exactly the right mounting dimensions a special motor or a modified standard is indicated. Overall efficiency of a drive is improved when the motor is applied as close to the point of utilization as possible, resulting

in a drive with few parts and maximum reliability.

By far the most motors are applied with foot mountings, driving through belts, chains or couplings. Foot mountings, whether installed horizontally or vertically on a bed, wall or ceiling have the advantage of universal simplicity and the convenience of adjustment for alignment or belt length. Most motors are designed for horizontal mounting. If vertical, wall or ceiling mounting is contemplated it becomes necessary to ascertain if the motor can be mounted in the position desired. With the shaft axis vertical, the bearings must have adequate thrust provisions to support the rotor weight. Motors with oil reservoirs must be positioned so that the oil will be retained and be capable of replenishment. Also, oil retention should be kept in mind when using this type of motor on applications where the motor may be tilted during operation. Sealed bearings of the antifriction type are usually designed to operate without regard to position.

Mounting dimensions of the foot for each frame size are given in TABLE 2. This shows the overall maximum dimensions of the feet, the diameter of holes or width of the slots in the feet, and the distances from the centerlines of the motor to the centerlines of the mounting holes. To simplify installation and adjustment, sliding bases or rails are available for the standard frames listed.

When direct drive through a coupling or gearing is desired, flange or face mountings are advantageous. In addition, self-contained units, shown in *Fig.* 8, often simplify installation. Many modifications of these types of mountings have been designed for special purposes, simplifying assembly, providing positive alignment with driven members, making a compact appearance, and saving floor area required by the machine. Accessibility for assembly and maintenance affect the selection of these mountings. The flange mounting has a bolt circle larger than that for a face mounting, but has the advantage of being assembled to the machine by bolting from the motor side of the flange. Face-mounted motors, having a smaller mounting diameter, *Fig.* 9, are applied in such a way that they can be bolted from inside the machine housing. In *Fig.* 10 is illustrated a special face mounting bracket on a tube cooling motor for use in airborne radar. Installation of this compact and lightweight motor requires minimum space in this complicated equipment. A special end flange in which the mounting circle is smaller than the motor diameter is shown

Table 5—Frame Sizes for Single-phase Motors (Horizontal and Vertical)*

(60-cycle, 115-230 volt)

Motor Type	No. of Poles	Synchronous Speed (rpm)	Frame Size for Horsepower Rating							
			½-Hp (No.)	¾-Hp (No.)	1-Hp (No.)	1½-Hp (No.)	2-Hp (No.)	3-Hp (No.)	5-Hp (No.)	7½-Hp (No.)
Open-type General-purpose	2	3600	...	...	...	203	204	224	225	254
	4	1800	...	...	203	204	224	225	254	...
	6	1200	...	204	224	225	254	...	...	...
	8	900	224	225	254	254	...	...	...	...
Totally-enclosed Motors	4	1800	...	...	224	225	254	...	...	...
	6	1200	...	224	225	254	...	...	...	...
	8	900	224	225	254	...	...	...	...	...
Totally-enclosed Fan-cooled Motors	2	3600	...	...	...	...	...	224	225	254
	4	1800	...	...	...	...	224	225	254	...
	6	1200	...	...	224	225	254	...	...	...
	8	900	224	225	254	254	...	...	...	...

* From NEMA Standards MG1-5.3, 5.5 and 5.6.

Table 6—Frame Sizes for Polyphase Motors—(60-cycle)

(Based on NEMA Adopted and Recommended Standards*)

Motor Type and Design	Enclosure for Frame	No. of Poles	Synch. Speed (rpm)	Frame Size for Horsepower Rating											Voltage Rating (v)
				½-Hp (No.)	¾-Hp (No.)	1-Hp (No.)	1½-Hp (No.)	2-Hp (No.)	3-Hp (No.)	5-Hp (No.)	7½-Hp (No.)	10-Hp (No.)	15-Hp (No.)	20-Hp (No.)	
Squirrel-cage Designs A and B	Open or Splash-proof	2	3600	...	...	...	203	204	224	225	254	284	324	326	110–550
		4	1800	...	...	203	204	224	225	254	284	324	326	364	...
		6	1200	...	203	204	224	225	254	284	324	326	364	365	208–550
		8	900	204	224	225	254	254	284	324	326	364	365	404	
		10	720	224	225	254	254	284	324	326	364	365	404	405	...
Squirrel-cage Designs A and B	Totally-Enclosed	2	3600	...	...	...	203	204	224	225	254	284	324	326	...
		4	1800	...	...	203	204	224	225	254	284	324	326	364	110–550
		6	1200	...	203	204	224	225	254	284	324	326	364	365	
		8	900	204	224	225	254	254	284	324	326	364	365	404	...
		10	720	224	225	254	254	284	324	326	365	...	...	...	...
Wound Rotor General-purpose	Open Frame	4	1800	...	...	...	...	224	225	254	284	324	326	364	110–550
		6	1200	...	...	...	...	225	254	284	324	326	365	404	...
		8	900	...	...	225	254	254	284	324	326	365	404	405	208–550
		10	720	...	...	...	...	324	326	365	404	405	444	445	

* From NEMA Standards MG1-5.7, 5.8, 5.9, 5.10, 5.11 and 5.12.

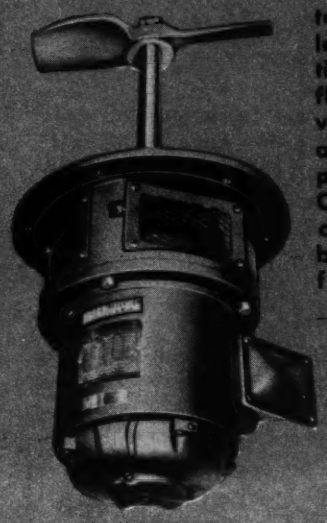
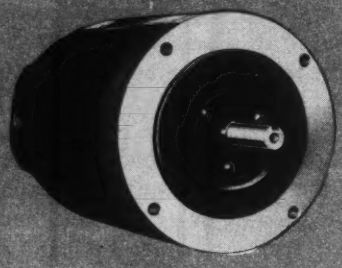


Fig. 8—Flange-mounted motor driving a fan for circulating air in a furnace. Vertical mounting through the floor of the furnace provides a compact, convenient assembly. Motor is a 3-phase induction motor with Class B insulation and special water cooling for the bearings to protect them from the furnace heat

—Courtesy, Reliance Electric & Eng. Co.



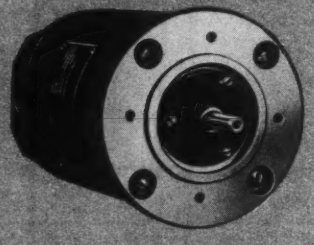
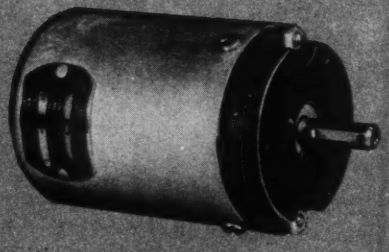


Fig. 9 — Type C face-mounted motors provide neat and compact drives. Mounting bolts are not visible when drive is installed. NEMA frames 42 and 56 are illustrated

—Courtesy, Doerr Electric Corp.



—Courtesy, Lamb Electric Co.

Fig. 10—Special face-type mounting for a 400 cycle, 115-volt, single-phase 1/100-horsepower motor for aircraft radar where space and weight are at a premium

in *Fig.* 11. This is accomplished by extending the bracket and recessing the mounting holes.

Standard dimensions for type *D* flanges on alternating-current and direct-current motors are shown in TABLE 8. When these flanges apply to vertical motors, the suffix letters *DV* or *SDV* are added to the frame numbers. Mounting dimensions for type *C* face-mounted motors, both alternating and direct-current, are listed in TABLE 9. According to the type of motor, its horsepower and speed, the frame number with which the mounting dimensions in TABLES 8 and 9 are identified is assigned.

Frequently, footless motors are purchased without a bracket on the shaft end and with shaft modifications for attaching a driven member. Applications for motors of this type are illustrated in *Figs.* 12 and 13, showing garbage disposal units. In each case the impeller and end bracket with seals and bearing are designed by the machine builder. When the motor is attached a compact integral unit results, yet minimum motor modifications by the motor builder are involved.

Shell-type motors probably provide the most versatile mounting when the utmost in the advantages of building a drive into its machine is desired. They consist merely of a shaftless rotor and stator. Laminations and coils of the stator are assembled in a cylinder or shell, carefully finished on the outside diameter for a press fit into a machine housing. There are no frame, end brackets, or bearings supplied with the motor. If a cooling fan is included, it is usually no larger than the rotor diameter. The machine housing into which the shell fits contains the bearings, and a machine spindle is pressed into the rotor to serve as the motor shaft. This mounting is decidedly advantageous when greater power is desired in a smaller diameter than is possible in conventional designs. Neat and compact drives are achieved in this manner.

Other shell motor advantages are obtained in revers-

Fig. 11—Special flange mounting in which mounting bolts are recessed in end bracket

—Courtesy, Westinghouse Electric Corp.

Fig. 12—Motor without end bracket mounted to garbage disposal unit, employing a Jack & Heintz motor

—Courtesy, National Rubber Machinery Co.

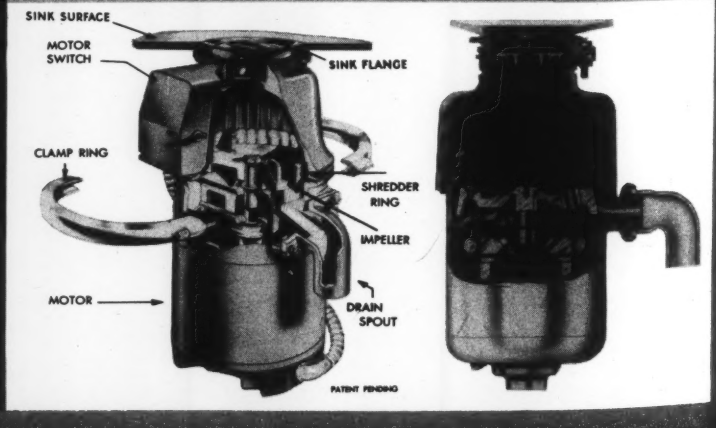


Fig. 13 — Garbage dis
al unit utilizing a Jac
Heintz motor supplied w
out end bracket, provi
integral design of

—Courtesy, Given Mf

Table 7—Frame Sizes for Direct-Current General Purpose Motors*

Motor Speed (rpm)	Frame Size for Horsepower Rating											
	½-Hp (No.)	¾-Hp (No.)	1-Hp (No.)	1½-Hp (No.)	2-Hp (No.)	3-Hp (No.)	5-Hp (No.)	7½-Hp (No.)	10-Hp (No.)	15-Hp (No.)	20-Hp (No.)	25-Hp (No.)
3500	...	...	...	203	204	224	225	254	284	324	326	326
1750	...	...	203	204	224	225	254	284	324	326	364	365
1150	...	203	204	224	225	254	284	324	326	365	...	...
850	204	224	225	254	254	284	324	326	365	...	...	...
690	224	225	254	254	284	...	...	...	...	...	...	...

* From NEMA Standards MG1-5.1 and 5.2 for horizontal and vertical motors, open type, 40 C motors. Frame sizes 324 and larger are suggested standards.

Table 8—Dimensions for Type D Flange-mounted Motors*

Motor Frame (No.)	Flange Diameters: Pilot AK (in.)	Flange Diameters: Bolt Circle AJ (in.)	Flange Diameters: Outside BD (max) (in.)	Distance from Flange to Shaft: End AH (in.)	Distance from Flange to Shaft: Shoulder BC (in.)	Shaft Diam U (in.)	Shaft Key: Width (in.)	Shaft Key: Thick (in.)	Clearance Hole BF: Size (in.)	Clearance Hole BF: (No.)
203D	9	10	11	2¼	0	¾	3/16	3/16	17/32	4
204D	9	10	11	2¼	0	¾	3/16	3/16	17/32	4
224D	9	10	11	3	0	1	¼	¼	17/32	4
225D	9	10	11	3	0	1	¼	¼	17/32	4
254D	9	10	11	3⅜	0	1⅛	¼	¼	17/32	4
284D	11	12½	14	3¾	0	1¼	¼	¼	13/16	4
324D	11	12½	14	4⅞	0	1⅝	⅜	⅜	13/16	4
326D	11	12½	14	4⅞	0	1⅝	⅜	⅜	13/16	4
364D	14	16	18	5⅝	0	1⅞	½	½	13/16	4
365D	14	16	18	5⅝	0	1⅞	½	½	13/16	4
404D	14	16	18	6⅜	0	2⅛	½	½	13/16	4
405D	14	16	18	6⅜	0	2⅛	½	½	13/16	4
444D	18	20	22	7⅛	0	2⅜	⅝	⅝	13/16	8
445D	18	20	22	7⅛	0	2⅜	⅝	⅝	13/16	8
504D	18	22	25	8⅝	0	2⅞	¾	¾	13/16	8
505D	18	22	25	8⅝	0	2⅞	¾	¾	13/16	8
364SD	14	16	18	3¼	0	1⅝	⅜	⅜	13/16	4
365SD	14	16	18	3¼	0	1⅝	⅜	⅜	13/16	4
404SD	14	16	18	3¾	0	1⅞	½	½	13/16	4
405SD	14	16	18	3¾	0	1⅞	½	½	13/16	4
444SD	18	20	22	4¼	0	2⅛	½	½	13/16	8
445SD	18	20	22	4¼	0	2⅛	½	½	13/16	8
504SD	18	22	25	4¼	0	2⅛	½	½	13/16	8
505SD	18	22	25	4¼	0	2⅛	½	½	13/16	8

* From NEMA Standard MG1-3.6.

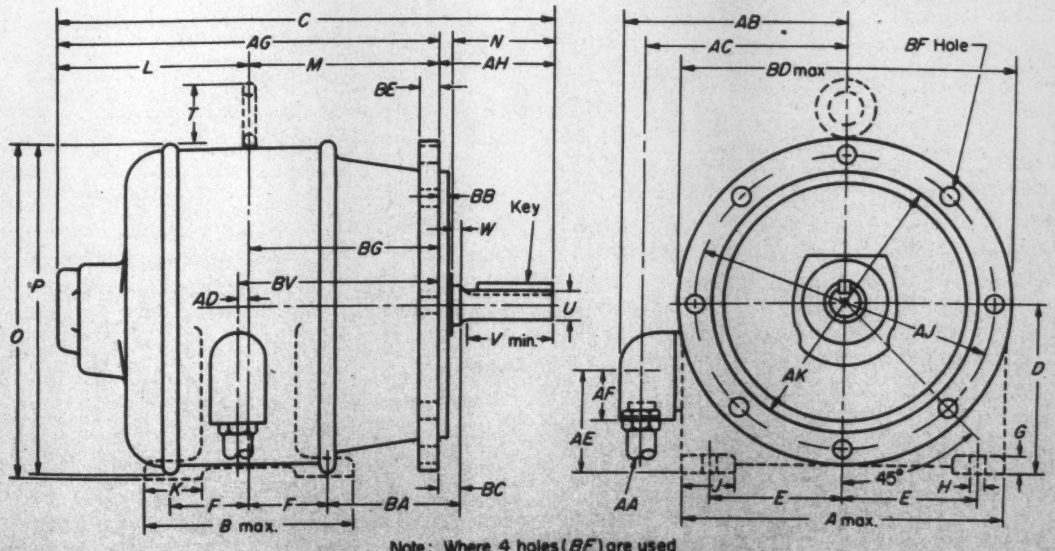
Tolerances—

AK Dimension—
203-326 frames, +0.000, −0.003-inch.
364-505 frames, +0.000, −0.005-inch.

Face Runout—
203-326 frames, 0.004-inch indicator reading.
364-505 frames, 0.007-inch indicator reading.

Permissible Eccentricity of Mounting Rabbet—
203-326 frames, 0.004-inch indicator reading.
364-505 frames, 0.007-inch indicator reading.

Permissible Shaft Runout—
203-326 frames, 0.002-inch indicator reading.
364-505 frames, 0.003-inch indicator reading.



Note: Where 4 holes (*BF*) are used they are on the 45 degree from the horizontal and vertical center lines

ing drives because connected rotating parts are minimized, effectively reducing the inertia forces in the drive. In reversing cycles this becomes important because the motor must supply sufficient energy to absorb the kinetic energy of rotation in one direction and accelerate the drive in the opposite direction restoring the energy. Most of this work absorbed by the motor as well as much of the energy supplied must be dissipated as heat from the motor. Each motor reversal is considered equivalent to four motor starts with respect to heat generation. Therefore any reduction in the inertia of couplings or connected parts is of great assistance to the motor in keeping heating at a low value.

For high-reversal applications, it is often advantageous to employ a sausage type (elongated rotor) to reduce the inertia of the motor itself. Dimensions for standard shell-type components are shown in TABLE 10. It should be noted that some motors are listed with two sets of dimensions, giving a choice of

Table 9—Dimensions for Type C Face-mounted Motors*

Motor Frame (No.)	Shaft Diam U (in.)	Face: Dist. to Shaft end AH (in.)	Face: Diameter: Bolt Circle AJ (in.)	Face: Diameter: Face Pilot AK (in.)	Face: Depth of Pilot BB (in.)	Face: Dist. to Shaft Shoulder BC (in.)	Face: Outside Diam BD (max) (in.)	Face: Dist. to Motor CL BG (in.)	Mounting Holes BF: (No.)	Mounting Holes BF: Tap Size	Mounting Holes BF: Min Depth (in.)	Shaft Key: Width (in.)	Shaft Key: Thickness (in.)
42C	3/8	1 1/16	3 3/4	3	1/8	1/16	5	2 33/64	4	1/4–20	..	..	..
48C	1/2	1 11/16	3 3/4	3	1/8	1/16	5 5/8	3 11/16	4	1/4–20	..	..	..
56C	5/8	2 1/16	5 7/8	4 1/2	1/8	1/16	6 1/2	4 1/16	4	3/8–16	..	..	..
66C	3/4	2 7/16	5 7/8	4 1/2	1/8	1/16	6 1/2	5 7/16	4	3/8–16	..	..	..
203C	3/4	2 1/16	7 1/4	8 1/2	1/4	1/16	9	...	4	1/2–13	3/4	3/16	3/16
204C	3/4	2 5/16	7 1/4	8 1/2	1/4	1/16	9	...	4	1/2–13	3/4	3/16	3/16
224C	1	3 1/8	7 1/4	8 1/2	1/4	1/8	9	...	4	1/2–13	3/4	1/4	1/4
225C	1	3 1/8	7 1/4	8 1/2	1/4	1/8	9	...	4	1/2–13	3/4	1/4	1/4
254C	1 1/8	3 3/4	7 1/4	8 1/2	1/4	3/8	10	...	4	1/2–13	3/4	1/4	1/4
284C	1 1/4	4 7/16	9	10 1/2	1/4	11/16	11 1/4	...	4	1/2–13	3/4	1/4	1/4
324C	1 5/8	5 5/16	9	10 1/2	1/4	1/16	12 1/2	...	4	1/2–13	3/4	3/8	3/8
326C	1 5/8	5 5/16	9	10 1/2	1/4	7/16	12 1/2	...	4	1/2–13	3/4	3/8	3/8
364C	1 7/8	5 3/8	11	12 1/2	1/4	—1/4	14	...	4	5/8–11	1 1/8	1/2	1/2
364SC	1 5/8	3	11	12 1/2	1/4	—1/4	14	...	4	5/8–11	1 1/8	3/8	3/8
365C	1 7/8	5 3/8	11	12 1/2	1/4	—1/4	14	...	4	5/8–11	1 1/8	1/2	1/2
365SC	1 5/8	3	11	12 1/2	1/4	—1/4	14	...	4	5/8–11	1 1/8	3/8	3/8
404C	2 1/8	6 1/8	11	12 1/2	1/4	—1/4	15 1/2	...	4	5/8–11	1 1/8	1/2	1/2
404SC	1 7/8	3 1/2	11	12 1/2	1/4	—1/4	15 1/2	...	4	5/8–11	1 1/8	1/2	1/2
405C	2 1/8	6 1/8	11	12 1/2	1/4	—1/4	15 1/2	...	4	5/8–11	1 1/8	1/2	1/2
405SC	1 7/8	3 1/2	11	12 1/2	1/4	—1/4	15 1/2	...	4	5/8–11	1 1/8	1/2	1/2
444C	2 3/8	6 7/8	14	16	1/4	—1/4	18	...	4	5/8–11	1 1/8	5/8	5/8
444SC	2 1/8	4	14	16	1/4	—1/4	18	...	4	5/8–11	1 1/8	1/2	1/2
445C	2 3/8	6 7/8	14	16	1/4	—1/4	18	...	4	5/8–11	1 1/8	5/8	5/8
445SC	2 1/8	4	14	16	1/4	—1/4	18	...	4	5/8–11	1 1/8	1/2	1/2
504UC	2 7/8	8 3/8	14 1/2	16 1/2	1/4	—1/4	18	...	4	5/8–11	1 1/8	3/4	3/4
505C	2 7/8	8 3/8	14 1/2	16 1/2	1/4	—1/4	18	...	4	5/8–11	1 1/8	3/4	3/4
504SC	2 1/8	4	14 1/2	16 1/2	1/4	—1/4	18	...	4	5/8–11	1 1/8	1/2	1/2
505SC	2 1/8	4	14 1/2	16 1/2	1/4	—1/4	18	...	4	5/8–11	1 1/8	1/2	1/2

* From NEMA Standard MG1-3.3.

Tolerances

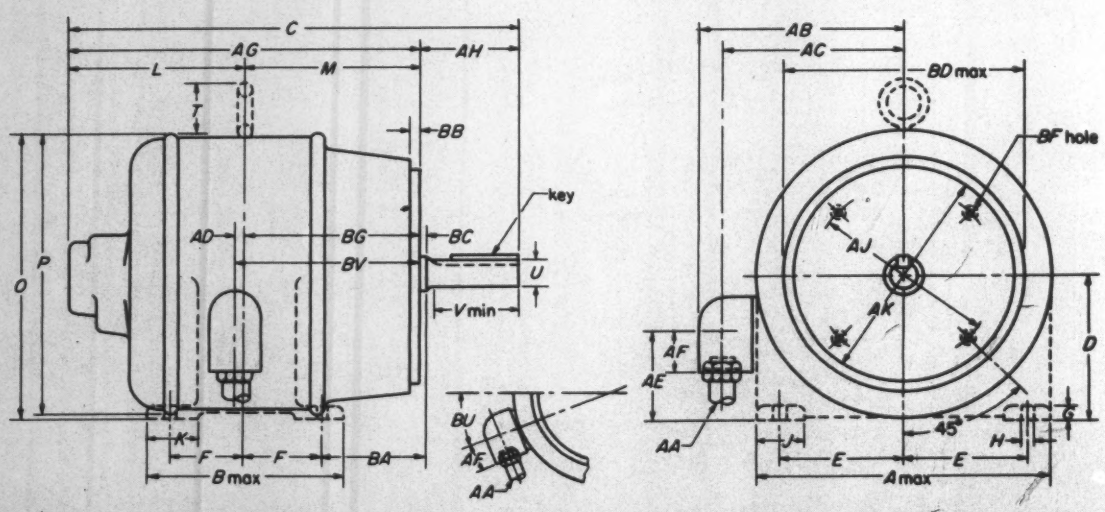
AK dimension—
42-66 frames, +0.000, —0.003 inch.
203-326 frames, +0.000, —0.003 inch.
364-505 frames, +0.000, —0.005 inch.

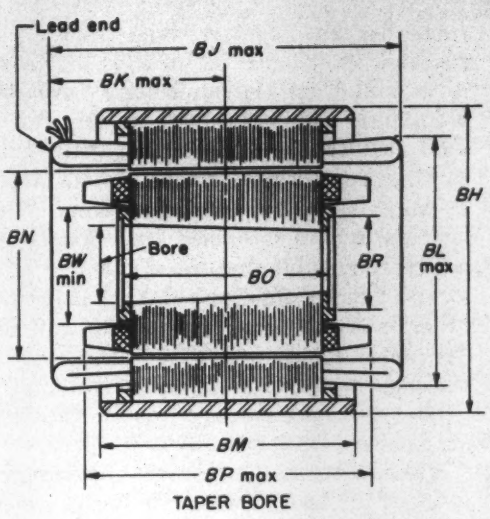
Face runout—
42-66 frames, 0.004-inch indicator reading.
203-326 frames, 0.004-inch indicator reading.
364-505 frames, 0.007-inch indicator reading.

Tolerances

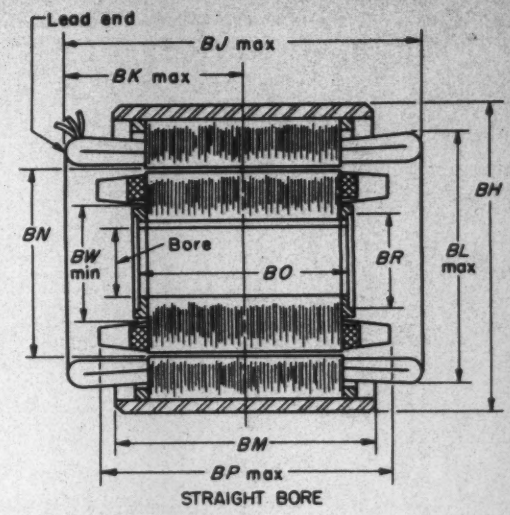
Permissible eccentricity of mounting rabbet—
42-66 frames, 0.004-inch indicator reading.
203-326 frames, 0.004-inch indicator reading.
364-505 frames, 0.007-inch indicator reading.

Permissible shaft runout—
203-326 frames, 0.002-inch indicator reading.
364-505 frames, 0.003-inch indicator reading.





TAPER BORE



STRAIGHT BORE

Table 10—Shell-type Motor Dimensions*

(for 3-phase, 60-cycle, open motors, 208-550 volts) (Based on NEMA Standards)

Horse-power (hp)	Max Length BJ				Shell Diam. B H (in.)	Rotor Straight Bore (in.)	Rotor Taper Bore (in.)	Rotor Key§ (in.)
	2-Pole (in.)	4-Pole (in.)	6-Pole (in.)	8-Pole (in.)				
½	....	....	....	6⅞				
¾	....	....	6⅛	7⅜				
1	....	6⅜	6⅞	8¾				
1½	6¾	7⅛	7⅜	10⅞	8	1½ to 2	1¾ to 2	⅜ x 3/16 ½ x ¼
2	7½	7⅝	8¾	....				
3	8	9	10⅞	....				
5	9⅜	11⅛	....	....				
7½	11½	....	....	....				
10	13½	....	....	....				
3	....	....	8⅝	10⅛				
5	....	9	10⅛	11⅞				
7½	9½	10½	11⅞	13⅝	10	1⅞ to 2⅜†	2.125 to 2.375††	⅜ x 3/16 ½ x ¼
10	11	12¼	13⅝	....				
15	12¾	14	....	....				
20	14½	....	....	....				
5	....	....	....	9⅞				
7½	....	....	9⅞	11⅛				
10	....	10⅜	11⅝	12⅝	12.375	2¼ to 2¾	2.5 to 2.75	½ x ¼ ¾ x ⅜
15	11	11⅝	12⅜	....				
20	12¼	12⅞	....	....				
25	13½	....	....	....				

* Some motors with ratings of 3-hp and larger are tabulated with 2 or 3 sets of dimensions. Based on NEMA Standard MG1-7.216.
† Max. bore for 2-pole motors is 2⅛ inches.
†† Max. bore for 2-pole motors is 2.25 inches.
§ Key size depends on rotor bore size.
Note: Max $BK = \frac{1}{2}\ BJ + \frac{1}{4}$

a longer but smaller diameter rotor for lower Wr^2 inertia or for closer mounting in multiple-spindle drives.

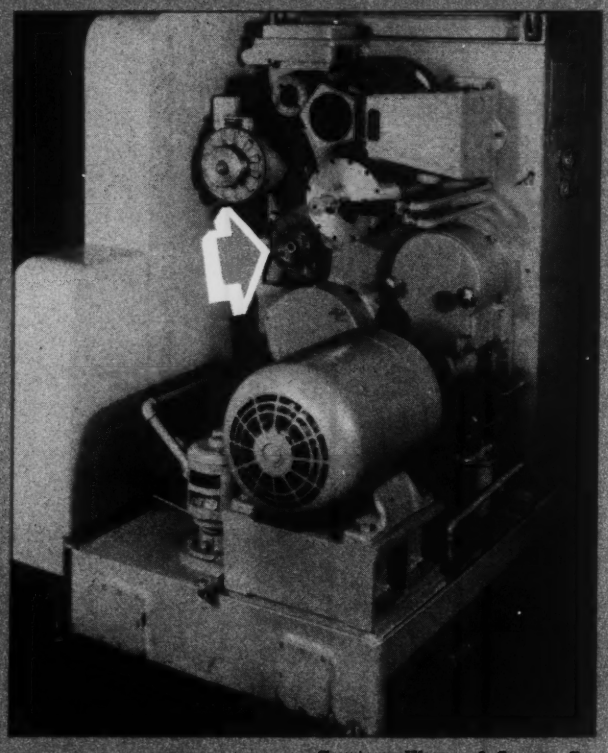
As well as being the most versatile mounting, shell-type motors probably have the most serious limitations. Mounting tolerances are critical because the air-gap concentricity depends upon the machining accuracies of the machine builder. Also, additional cumulative errors may be introduced by added machining operations and any increased variation in the air gap would affect motor performance. In other words, the concentricity of inner and outer diameters of the shell and the concentricity of the bore in the machine housing with the bearing brackets involve additional machining setups. The bore in the rotor into which the machine builder presses his shaft or spindle involves additional tolerances not incurred in conventional motor construction. These complications, together with the necessity of the machine builder providing for motor ventilation, are responsible for the fact that motor manufacturers assume only limited responsibility for shell-type motor performance.

More elaborate assembly setups are necessary, requiring facilities for press fitting both the stator into the machine housing and the shaft into the rotor. Also, from the viewpoint of maintenance, these are limitations requiring the service man to perform operations involving equipment which may not be available readily.

Shell-type motors, however, have proved exceptionally advantageous on buffers, grinders, machine tools, woodworking machines, hoists, conveyors, textile machines, etc.

Illustrated in *Fig.* 14 are the index motor (top), rapid traverse motor (center) and main drive motor (bottom) for a single-spindle automatic. The rapid-traverse motor is a shell type, 1-horsepower, 1200

Fig. 14 — Index, rapid-traverse and main-drive motors on a single-spindle automatic. The rapid-traverse motor (center) is shell type



—Courtesy, Warner & Swasey Co.

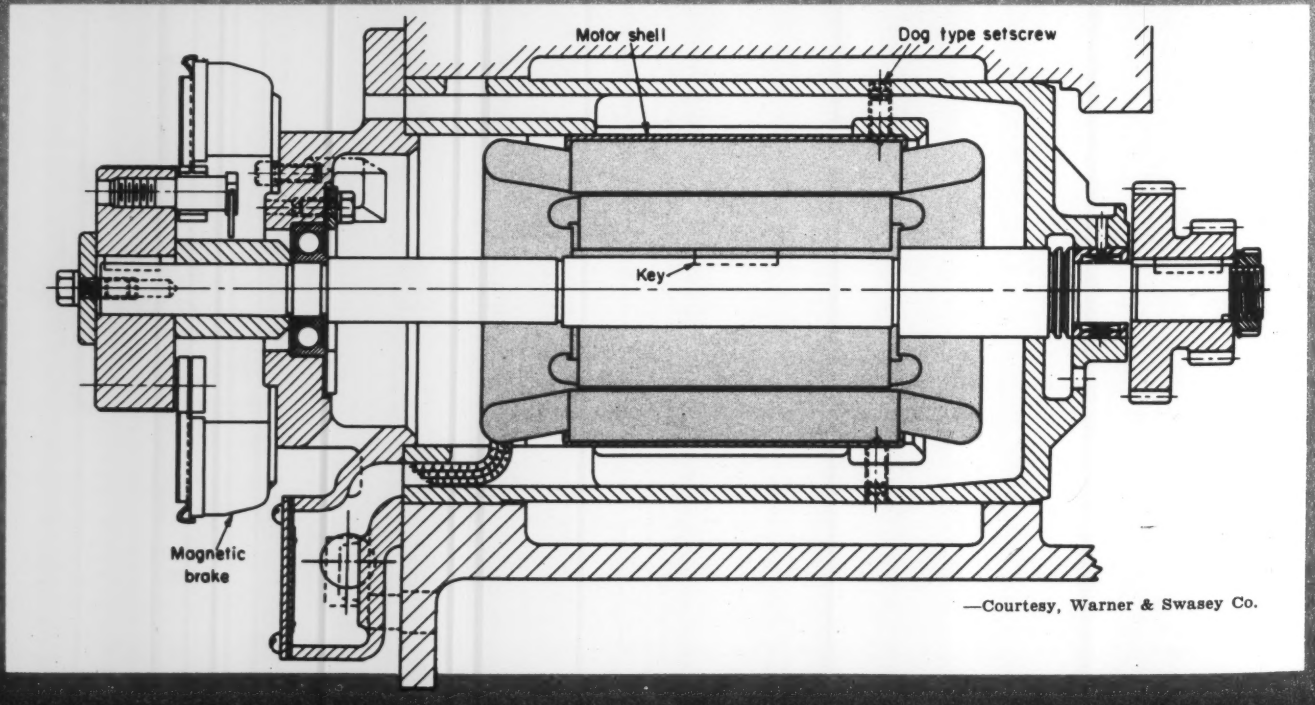
rpm, 3-phase squirrel-cage motor. Its mounting features are illustrated in *Fig.* 15. A magnetic brake is mounted on the front end (outboard) for quick stopping. The shell type motor was chosen to provide unit construction in the limited space available. In this application its use effects a lower total cost by simplifying mounting problems. The motor is not a press fit, but is locked with dog type screws and is easily removable for maintenance. The ball bearing at the front end is locked to position the motor. The other end has a roller bearing and is free to float. The index motor is a 1/3-horsepower, 1200-rpm squirrel-cage motor and the main motor is 10-horsepower, 1800-rpm, squirrel-cage motor capable of reversing six times a minute at lowest speed.

Various forms of resilient mountings have been developed for foot, bracket or flange mounting, generally in the small fractional-horsepower sizes. One type, standard with many manufacturers, is a resilient foot mounting, cradling the motor between synthetic-rubber rings surrounding the shaft bearings at each end of the motor as shown in *Fig.* 16. These motors are widely employed in sizes up to 1/3 horsepower for belt-driven refrigerator compressors, fans, blowers and stokers. For shaft-mounted fans and blowers they are standard up to ¾ horsepower.

Methods of mounting small and miniature motors are almost unlimited. Some resilient types have rubber grommets in the mounting holes. An effective mounting of this type, *Fig.* 17, has cup washers in the mounting hole so that the attachment bolts may be drawn tight, giving the proper compression to the grommets for resiliency without danger of the bolts loosening.

Other types of mounting employ a flat strap over the motor diameter. This inexpensive method has

Fig. 15—Mounting arrangement and ventilation provisions for shell-type rapid-traverse motor



—Courtesy, Warner & Swasey Co.

the advantage that the motor manufacturer need not supply a special mounting. The motor style or size may be changed readily with a simple modification of the strap assembly. In another interesting method the manufacturer provides extensions of the end-bell bolts for a simple, inexpensive and convenient mount. In *Fig.* 18 is illustrated a capacitor motor having extended through-bolts. This motor is employed to drive a fan, the bolts simplifying installation.

A vibration absorbing mount for a motor and blower is illustrated in *Fig.* 19. In this installation a simple attachment was sought that would isolate vibrations in the system. The result is an end bracket on the motor resiliently mounted on the blower housing. A Sirroco type impeller is mounted direct on the motor shaft and surrounds the motor frame.

Mountings particularly suitable for certain types of applications include the floating type wherein the motor is mounted on its hollow shaft which in turn is supported by the shaft of the machine. The motor bearings permit the stator to float, restrained only by a torque arm. Such an installation is shown in *Fig.* 20 where this type of motor is installed on each roll in a steel mill runout table. Advantages of this type of drive include simplicity of installation and ease of installation in that no alignment problem exists between motor and its driven member. Entire motor and its connected roll may be removed and replaced simply.

The sectional drawing in *Fig.* 21 illustrates the hollow shaft design of the motor and the method for mounting on the shaft roll. Mounting is accomplished by slipping the hollow shaft motor over the roll shaft and tightening the jack screw. Roll shaft and hollow motor shaft are keyed together and operate as an integral unit. The conventional bearings on the motor serve only to keep the rotor and stator concentric, motor torque being delivered to the roll by the use of a lug on the motor frame being held from rotating by a torque arm. Between the torque arm and lug are springs and universal joints to maintain floating features of the motor.

Illustrated in *Fig.* 22 is a cutaway view through a dc motor serving as individual drive axles for the heavy-duty tractor illustrated in *Fig.* 1. Driving through planetary reduction gears this specially designed series type of brakemotor applies its torque direct at the wheel obviating clutch, transmission and differential. When current is cut off, the multiple-disk brake is automatically applied by spring tension. To relieve load on the brake and allow down-hill controlled travel, regenerative braking of the motor is employed.

Bearings: In applying a motor, bearing types are usually selected, depending on the duty, with respect to life, contaminants present, ambient temperature, etc. With respect to life, bearings on standard, special and definite-purpose units are adequate insofar as the expected life and quality of the motor in general are concerned.

Sleeve or ball bearings are optional choices on many motor sizes. Properly fitted ball bearings often require less maintenance and have a lower

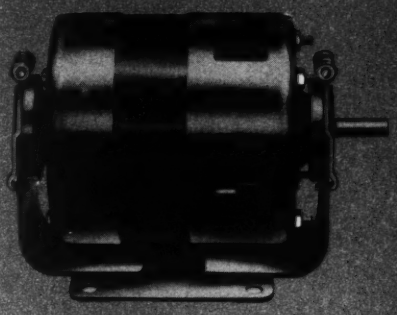


Fig. 16—Resilient type of mounting for fractional-horsepower motors used on stokers, fans and blowers. This is a 4-pole shaded-pole motor

—Courtesy, Fasco Industries Inc.

—Courtesy, Redmond Co. Inc.

Fig. 17—Resilient mounting for small motors using spacer washers to compress rubber grommet to proper amount with mounting bolt

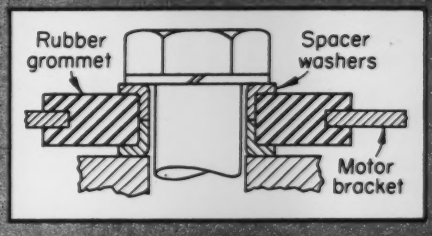
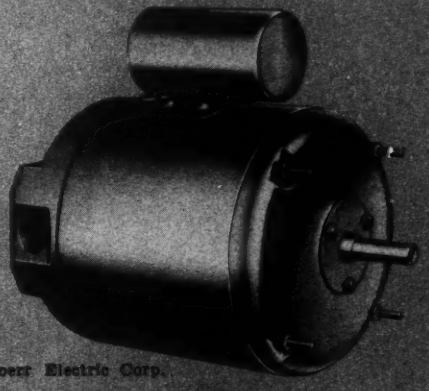


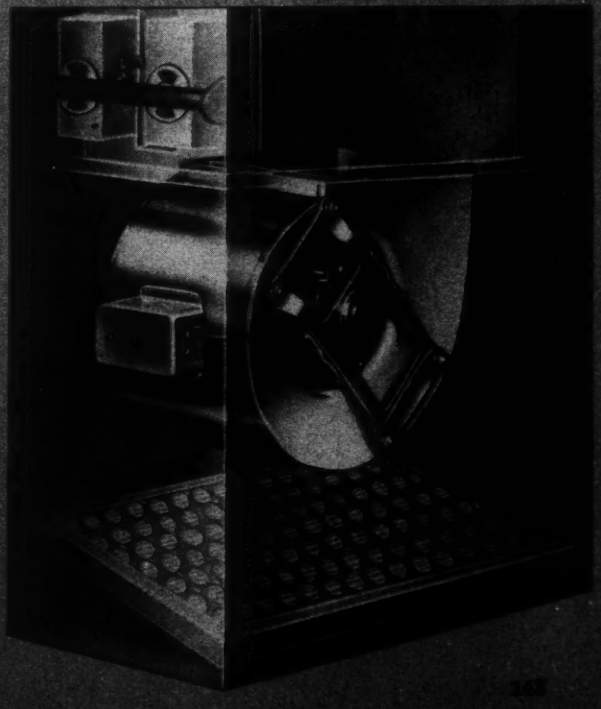
Fig. 18—Extended through bolts on this two-speed capacitor motor simplify installation in ventilating system



—Courtesy, Doerr Electric Corp.

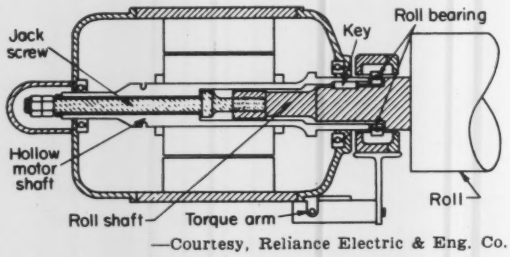
Fig. 19—End-bracket mounting resiliently attached to blower housing isolates vibrations from the system

—Courtesy, Fasco Industries Inc.



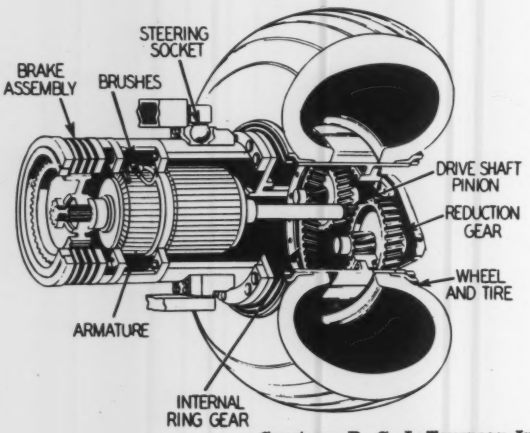
—Courtesy, Reliance Electric & Eng. Co.

Fig. 20—Floating motor mounting on runout table drive eliminates alignment problems, simplifying maintenance



—Courtesy, Reliance Electric & Eng. Co.

Fig. 21—Design features of hollow-shaft floating motor, showing method of mounting



—Courtesy, R. G. LeTourneau Inc.

Fig. 22—Motor wheel mounted as drive axle on tractor. Spring energized disk brake holds tractor when motor is de-energized. Regenerative braking is utilized for overhauling loads

breakaway torque, an advantage in applications involving frequent starting. Offset against these features are increased motor costs for small motors. For some integral-horsepower motors the prices are equal. Ball bearings may be grease packed, having seals and provisions for lubricant renewal with safeguards against overgreasing. Because entrance of abrasives in a ball bearing is more damaging than in a sleeve bearing, bearing seals are important, serving the dual purpose of excluding contaminants and retaining lubricants. Some sealed bearings have no provision for lubrication, being sealed for life and guaranteed by the manufacturer.

Sleeve bearings are of two general types, plain and porous or "oilless." Plain bearings are supplied with lubricant reservoirs containing waste or felt for wick feeding, or an oil ring. Oil is replenished in porous types either by wick or an oil cup. Inexpensive miniature motors with porous bearings often have no oil reservoir, occasional application of oil on the bearing sufficing. For vertical mounting or for driving fans or similar loads, sleeve bearings require additional provisions for thrust. This is provided by thrust bearings on shaft shoulders or on the inboard end of the shaft if thrust is applied only in that direction.

Insulation: Insulation for a motor is chosen primarily for its ability to retain its properties at elevated temperatures. Other considerations, however, are frequently involved, such as resistance to chemical fumes or other corrosive atmospheres, to severe shock or vibrations, and to fungus growth and attack such as encountered in the tropics. Generally insulation for motors has been classified into three groups: Class *A*, Class *B* and Class *H*.

CLASS *A:* Impregnated cotton, silk or paper; phenolic and similar plastics; cellulose derivatives; and varnishes are classified as Class *A* insulation. These materials include the general group of insulations employed on motors and are satisfactory for standard temperature rise of 40 C in open motors and 55 C in enclosed types. Choice of the insulation for unusual conditions involves the presence of abrasive or conductive dust, moisture, and corrosive fumes.

Motors suitable for service in the tropics may require special treatment to withstand high ambient temperatures, excessive moisture, fungus, insects, vermin or corrosion. Protection against insects or

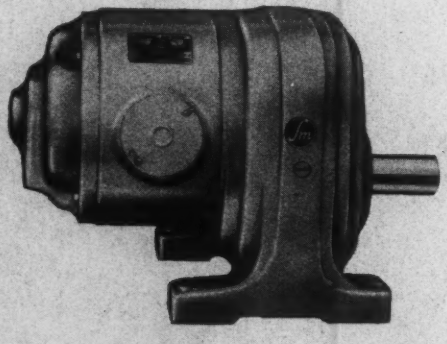
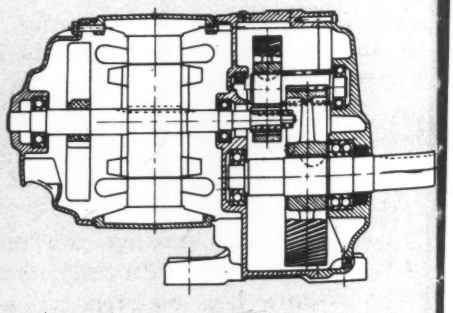


Fig. 23—Double-reduction gearmotor having a dripproof enclosure for the motor frame. Motor is mounted on the gearcase which has standard foot mounting. Output shaft is on same vertical centerline with motor shaft, but displaced below as shown in the sectional drawing

—Courtesy, Sterling Electric Motors



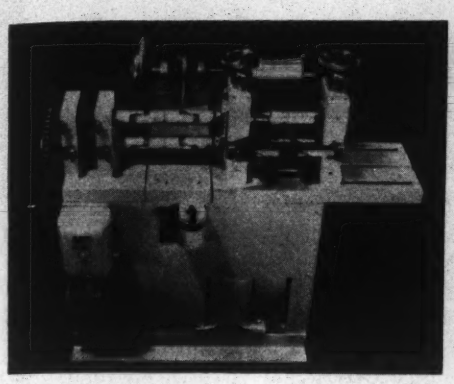


Fig. 24—Gearmotor drive in base of roll-forming machine reduces installation costs by simplifying assembly

— Courtesy, Sterling Electric Motors

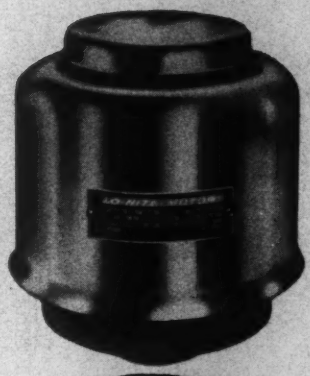
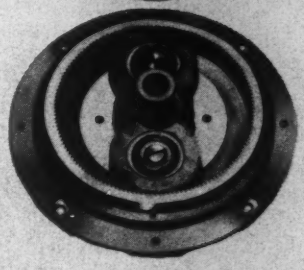


Fig. 25—Planetary gearing provides 10 to 1 reduction and concentric drive without materially increasing length of motor for floor polishing machines

—Courtesy, The Brown-Brockmeyer Co.



vermin involves the addition of screens over all openings or enclosed frames. Protection against fungus and corrosion normally requires a special treatment on the insulation and metal surfaces. Protection against excessive moisture requires a special Class *A* material. Protection against excessive heat (more than 104 F) requires Class *B* insulation. When excessive moisture or other corrosive condition is present, a totally-enclosed nonventilated motor may be required.

CLASS *B:* Fiberglass and similar inorganic materials such as mica and asbestos with organic binding substances comprise Class *B* insulations. With these insulations, Class *A* materials are sometimes employed for structural purposes but they must not impair the continuous duty properties of the insulation. These motors may be rated for the same temperature rise as Class *A* but can also be supplied as special for temperatures of 70 or 75 C rise. Motors having Class *B* insulation and standard temperature ratings may be operated at altitudes up to 15,000 feet without excessive heating when the ambient does not exceed 40 C.

CLASS *H:* Silicone insulation and fiberglass impregnated with silicone are Class *H* insulations. One of the most obvious limitations of silicone insulations is its price. Prices having been reduced during the past few years, it seems probable that further reductions will follow increased production. Semivulcanized silicone tapes reinforced with glass cloth have greatly increased the usefulness of the insulation. As an outer wrapping on field coils, oven cured, the silicone is vulcanized to form a resilient, void-free, moisture-proof and oil resisting jacket with excellent dielectric properties and high thermal conductivity. It is stable at temperatures ranging from −70 to 500 F. As insulation for diesel-electric locomotive motors and industrial motors exposed to severe operating conditions, it has proved superior to other insulations.

Auxiliaries: Auxiliaries built into motors provide neat compact drive packages, simplifying the designer's work and usually reducing or eliminating the external components required, thus simplifying assembly to the machine. Available in a wide variety of types and styles, such auxiliaries include gearing, transmissions, hydraulic couplings, clutches and

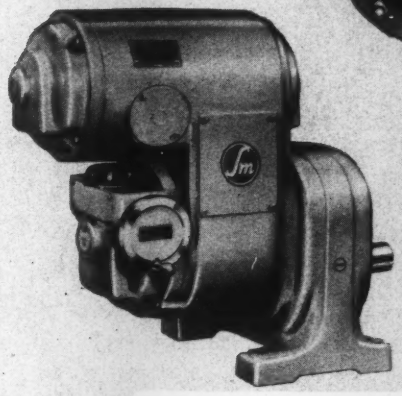
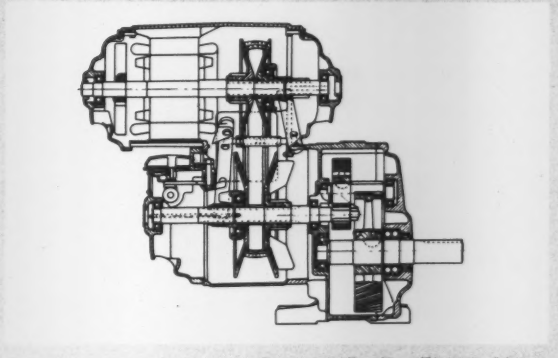
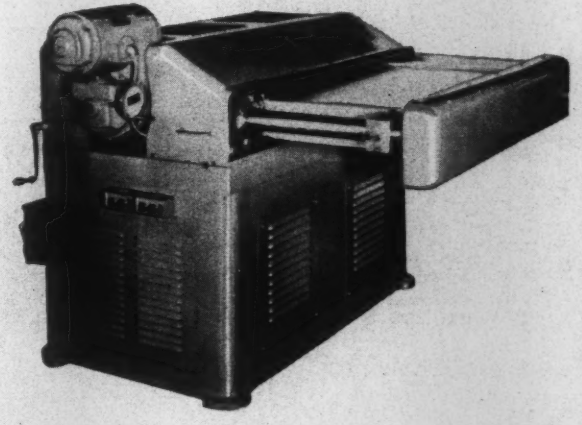


Fig. 26—Mechanical variable-speed transmission built into motor drive unit, providing an exceptionally compact unit. Sectional view shows arrangement of motor, variable-speed unit and reduction gearing



—Courtesy, Sterling Electric Motors

Fig. 27—Motor with built-in variable-speed transmission and gear reducer drives a Whitman's automatic candy machine, providing speed control to match conveyor speed



—Courtesy, Sterling Electric Motors

—Courtesy, Reeves Pully Co.

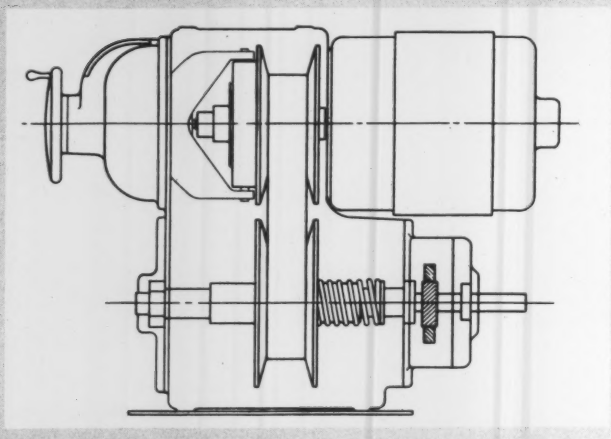
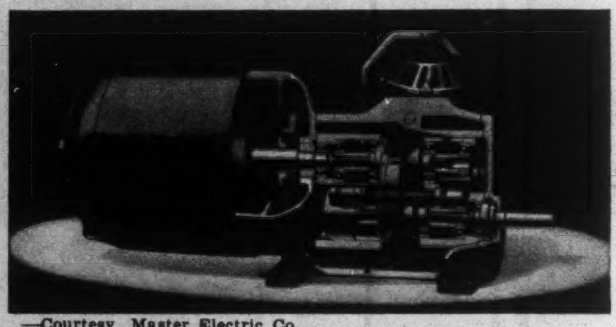
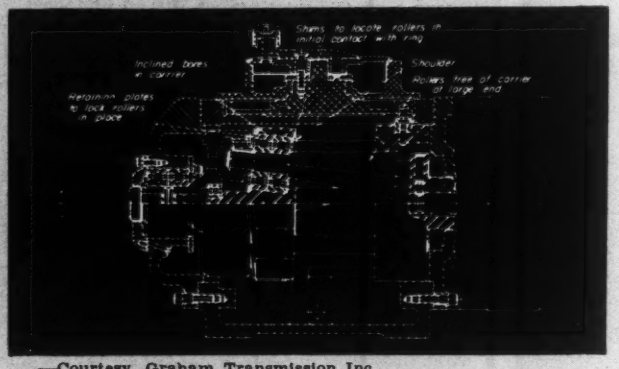


Fig. 28—Variable-speed transmission flange mounted on a fractional-horsepower motor



—Courtesy, Master Electric Co.

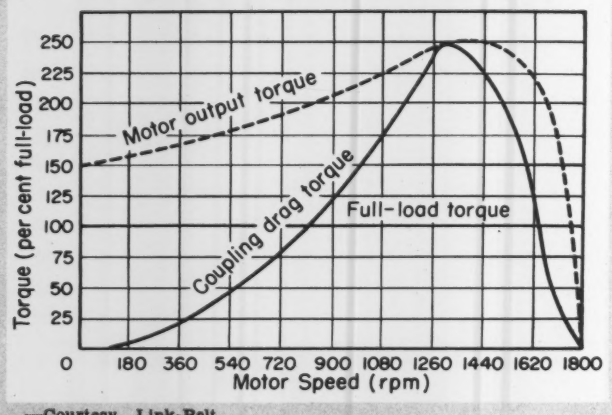
Fig. 29—Variable-speed motor-transmission for providing 8 to 1 speed adjustment



—Courtesy, Graham Transmission Inc.

Fig. 30—Variable-speed transmission employing friction driven cones and planetary gearing

Fig. 31—Relationship between hydraulic coupling drive and conventional motor for torque-speed characteristics



—Courtesy, Link-Belt

brakes, as well as speed governors and thermal overload protection.

GEARMOTORS: Applied exactly as conventional motors, considering output speed, torque characteristics and duty cycle, gearmotors can be smaller overall than a comparable motor when relatively slow output speeds and high torque are involved. In addition, more advantageous torque relations are obtainable. In gearing, the torque is inversely proportional to the speed. This advantage is not attainable to such a degree in electrical design, particularly at starting and during acceleration when high torque is desirable for most drives.

Generally where machine driveshaft speeds are below 900-600 rpm, the gearmotor has superior drive characteristics with this advantage increasing as the speed decreases. For instance, a 5-horsepower motor, for direct drive at 600 rpm is compared with a 5-horsepower gearmotor at the same speed in TABLE 11. Also, at speeds below 600 rpm, the gearmotor has a cost advantage as well as a physical size advantage.

Different classes of service have made it desirable to provide more than one gear size for the same horsepower and speed rating. The American Gear Manu-

Table 11—Comparison of Motor and Gearmotor
(5-horsepower, 600 rpm)

Type of Drive	Efficiency* Half-Load (%)	Efficiency* Full-Load (%)	Power Factor Half-Load (%)	Power Factor Full-Load (%)	Starting Torque† (%)
Gearmotor*	81	82	81	90	150
Slow-speed motor .	79	81	46	66	115
Gearmotor advantage	2	1	35	24	35

* Gearmotor efficiency is based on entire unit including gearing loss of 2%.
† Starting torque is based on percentage of full-load torque.

facturers Association have designated three classes for this purpose as follows:

CLASS I: For steady loads not exceeding the normal rating of the motor and 8 hours per day service, or for moderate shock loads where service is intermittent

CLASS II: For steady loads not exceeding the normal rating of the motor and 24 hours per day service, or for moderate service or moderate shock loads 8 hours per day

CLASS III: For moderate shock loads and 24 hours per day service, or for heavy shock loads running 8 hours a day.

Inasmuch as all applications do not fall into these categories, interpolation between severity and frequency of intermittent loads may be made.

Gearmotors are available as single, double or triple-reduction units with spur or helical gearing, *Fig.* 23. Also worm and planetary gear reductions are widely employed for high reductions and when the right-angle or concentric construction are advantageous. Nominal reductions for parallel gearing have been standardized in a geometric series with steps of approximately 1.225. This provides for 30 ratios ranging in reductions from 1.225 to 437.875, giving output

Table 12—Gearmotor Output Speeds*

Nominal Gear Ratio†	Output Speed§ (rpm)	Nominal Gear Ratio†	Output Speed§ (rpm)
1.225	1430	25.628	68
1.500	1170	31.388	56
1.837	950	38.442	45
2.250	780	47.082	37
2.756	640	57.633	30
3.375	520	70.623	25
4.134	420	86.495	20
5.062	350	105.934	16.5
6.200	280	129.742	13.5
7.594	230	158.900	11.0
9.300	190	194.612	9.0
11.390	155	238.350	7.5
13.950	125	291.917	6.0
17.086	100	357.525	5.0
20.926	84	437.875	4.0

* For integral-horsepower gearmotors of parallel construction (NEMA Standard MG1-6.12).

† Variations in ratios should not change output speed by more than ±3%.

§ Based on assumed motor (4-pole) speed of 1750 rpm at 60 cycles. Same gear ratios apply for 6-pole motors, assuming a motor speed of 1165 rpm. Gear ratios also apply to 25 or 50-cycle gearmotors having an assumed motor speed of 1430 rpm (2 and 4-pole, respectively).

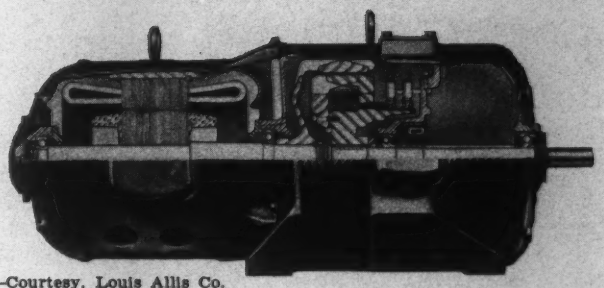
speeds from 1430 to 4.0 rpm with a 1750-rpm drive motor as shown in TABLE 12. Other than 4-pole, 60-cycle motors are applied also to these gear ratios. For 25 or 50-cycle motors, motor operating speed of 1430 is used and for 6-pole, 60-cycle motors a motor speed of 1165 rpm is standard. Other speeds and gear ratios would be classified as special.

In *Fig.* 24 is shown a double-reduction gearmotor driving a light-metal forming roll built by the Slagle Beryllium Co. The drive problem, in addition to providing desired speed-torque requirements, necessitated a compact drive unit located in restricted space in the base. In applying the gearmotor instead of separate motor and reducer, 50 per cent production time is saved together with resultant savings in direct labor and indirect labor costs.

To conserve axial length and provide a concentric output shaft in a high-reduction gearmotor, planetary gearing, *Fig.* 25, may be employed. Output speed of this ½-horsepower repulsion-start induction motor is 179 rpm from a motor speed of 1795 rpm. This motor was specially developed for floor polishing and scrubbing machines to provide a short motor with a high starting torque. This torque is 400 per cent of full-load running torque.

Linear actuators, translating the rotary motion of the motor into linear movement through gearing are employed for positioning mechanisms and are used widely in aircraft auxiliaries. Strokes are somewhat limited in length and reversing motors, with limit switches on the linear travel, drive such units.

TRANSMISSIONS: Although adjustable speeds are obtainable through electrical controls, mechanical variable-speed transmissions are available with motors as a combination unit, with or without gear reductions. One type, using a belt and variable-diameter pulleys, has an adjustable speed range up to 10:1 with the motor operating at constant speed and constant horsepower. Such a drive is illustrated in *Fig.* 26 and is shown applied to a candy machine in *Fig.* 27. Another belt-type variable-speed transmission, *Fig.* 28, suitable for 10 to 1 reductions is shown with a



—Courtesy, Louis Allis Co.

Fig. 32—Eddy-current clutch, flange mounted on a general-purpose motor to provide adjustable variable speeds

—Courtesy, Louis Allis Co.

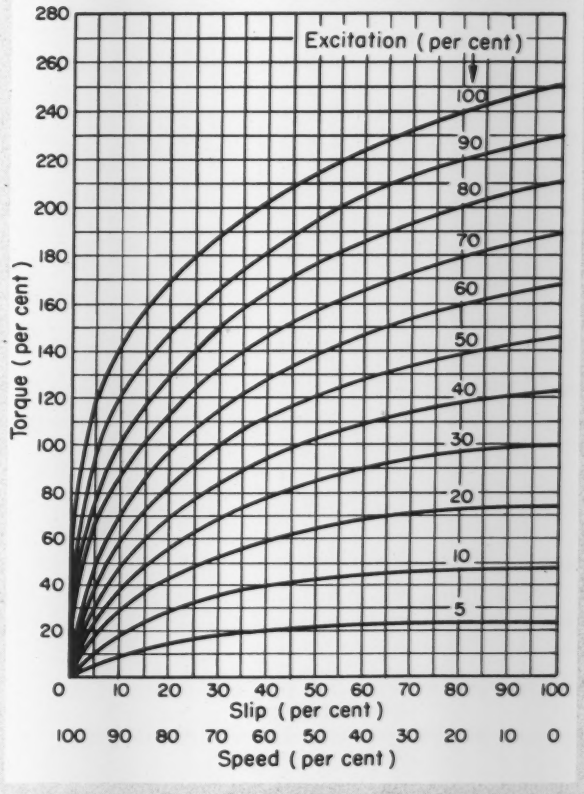
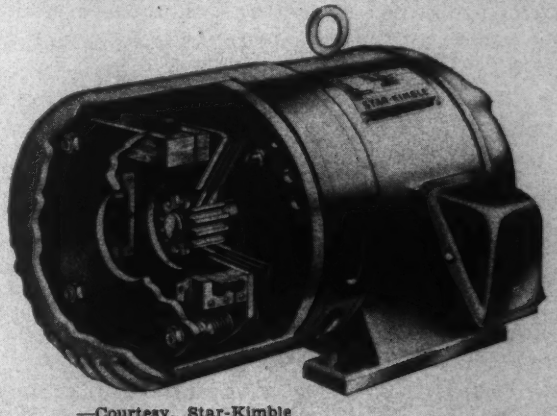


Fig. 33—Typical torque curves for an eddy-current clutch

Fig. 34—Brake-motor drive has brake adjusted to match machine braking requirements



—Courtesy, Star-Kimble

—Courtesy, Star-Kimble

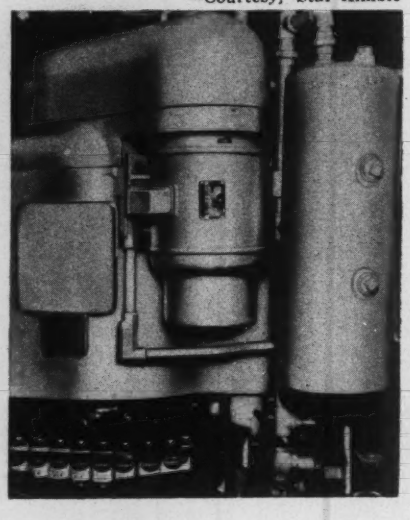
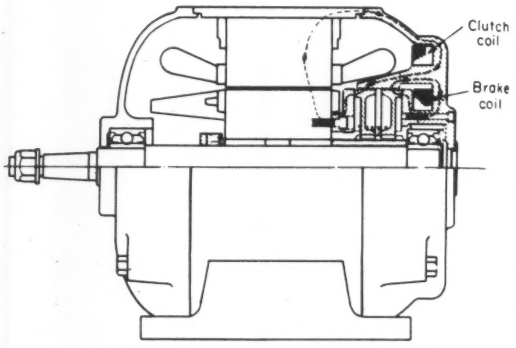


Fig. 35—Brakemotor driving a machine for sealing cans at 300 an hour. The brake automatically stops the machine within one can in event of a jam



—Courtesy, Warner Electric Brake & Clutch Co.

Fig. 36—Sectional view of clutch-brakemotor showing novel flux paths through frame for both clutch and brake

flange-mounted fractional-horsepower motor.

The sectional view in *Fig.* 29 illustrates the features of another type of infinitely-variable transmission employing a steel ring to contact two sets of adjustable diameter pulleys. Turning the control knob adjusts the pulleys to give an 8 to 1 speed range.

In *Fig.* 30 is a variable-speed auxiliary which employs two cones driven by a spider. The position of a stationary ring along the surface of the cones controls the speed of planetary gears on the cones, varying the speed of a ring gear mounted on the output shaft.

CLUTCHES AND BRAKES: With the increasing speeds of operation, more precise positioning, and shorter transfer intervals which are being demanded of machines, brakes and clutches are becoming a necessary part of many drives. As with gearing, these devices are designed into the motor as integral auxiliaries, making for neater and more compact installations, and simplifying the designer's tasks.

Centrifugal, hydraulic, eddy-current, magnetic-particle, and magnetic clutches usually serve one of two important functions. More commonly, they are employed to start high inertia loads, relieving the motor of starting the burden from standstill. With the motor running or idling before clutch engagement, the current input into the motor is not as high as when the load is applied direct to the motor. If starts are frequent, this system reduces motor heating, increases motor cooling during idling periods (increased ventilation), and often allows the use of a smaller motor. The second function involves those applications where it may be desirable to start and stop a machine spindle quickly and where the inertia of the motor rotor would be an excessive burden.

Hydraulic couplings are used only for the first type of application in that their slip and engagement are automatic depending on the motor speed and load. They allow the motor to accelerate almost to full speed before beginning to pick up the load. They also tend to cushion momentary peak loads. When connected to a motor, hydraulic couplings provide characteristics shown in *Fig.* 31 which are much like those of a Design *D* high-slip motor. These curves illustrate that the particular motor alone could start a load of 150 per cent full-load torque, whereas with the coupling allowing the motor to develop 250 per cent torque the drive could pick up this starting load even though the motor by itself would fail to start. Another interesting feature of the coupling drive is that the coupling transmits (minus losses) the torque attained by the motor as it accelerates from zero speed to load speed.

Centrifugal clutches also have characteristics designed into them which generally cannot be varied. Usually they are of the governor-ball type with an overcenter linkage or a mercury-displacement type that engages friction elements at a predetermined speed during motor acceleration. This allows the motor to develop near-maximum torque before clutch engagement. Also the motor can slow down somewhat over this value from overload before the clutch disengages. In this way they serve as a safety cut-out in addition to a starting device.

Eddy-current clutches, *Fig.* 32, utilized as auxiliaries on general-purpose motors provide an adjustable variable-speed drive (adjustable torque). Amount of excitation supplied to the clutch effects adjustable torques available at the driveshaft, controlling the speed output. In the sectional view illustrated, provisions are made for inclusion of an eddy-current brake on the shaft beyond the clutch. Torque transmission of a typical clutch for various excitations is indicated in *Fig.* 33.

Magnetic-particle fluid clutches usually have provisions for the control of engagement and transmitted torque. This is accomplished by varying the current or voltage flowing in the clutch circuit. These clutches are often employed for adjustable speed control. In special forms, however, with permanent magnets, control may be effected by varying the gap between the magnet poles.

Magnetic-particle fluid clutches operate on the principle of fine iron particles, often suspended in an oil medium, being attracted to form "chain paths" in a magnetic field. With a weak field or no field there is

no attraction and the clutch is disengaged. As the field is strengthened by ampere turns of current flowing, the field in the fluid medium is strengthened. When saturation is reached, the chain of iron particles form a "solid sludge" and transmit full torque. Magnetic fields in between these extremes create a drag torque proportional to the field, effecting speed control.

Brakes differ from clutches only in method of application. Most of the principles utilized in clutches generally are employed in brakes with the exception, perhaps, of centrifugal and hydraulic clutches because both depend on speed for operation. Brakes may differ with respect to control also in that they may operate on the "dead-man" or "fail-safe" method of control. This should always be considered in brake applications. In this type of control, the brakes are engaged by spring pressure or a similar mechanism not dependent on electric current energization. On hoists, for instance, if the power fails it is desirable that the brakes are applied automatically as a safety measure. In such brakes, a closed electrical or magnetic circuit holds the brakes in released position. Opening the circuit applies the brakes.

An interesting spring-applied brake on torque motors sets the brake when the motor is de-energized by shifting the rotor axially into engagement with a friction disk. Energization of the motor releases the brake by action of the motor field pulling the armature axially into its central position.

In *Fig.* 34 is a sectional view of a brakemotor. This magnetic brake unit is a dead-man type. When the brake is engaged, springs press a nonrotating friction disk against metal disks splined on the motor shaft. When the motor circuit is closed, energized magnet coils, acting against the springs, release the brake. The disks are designed for short travel to provide fast action.

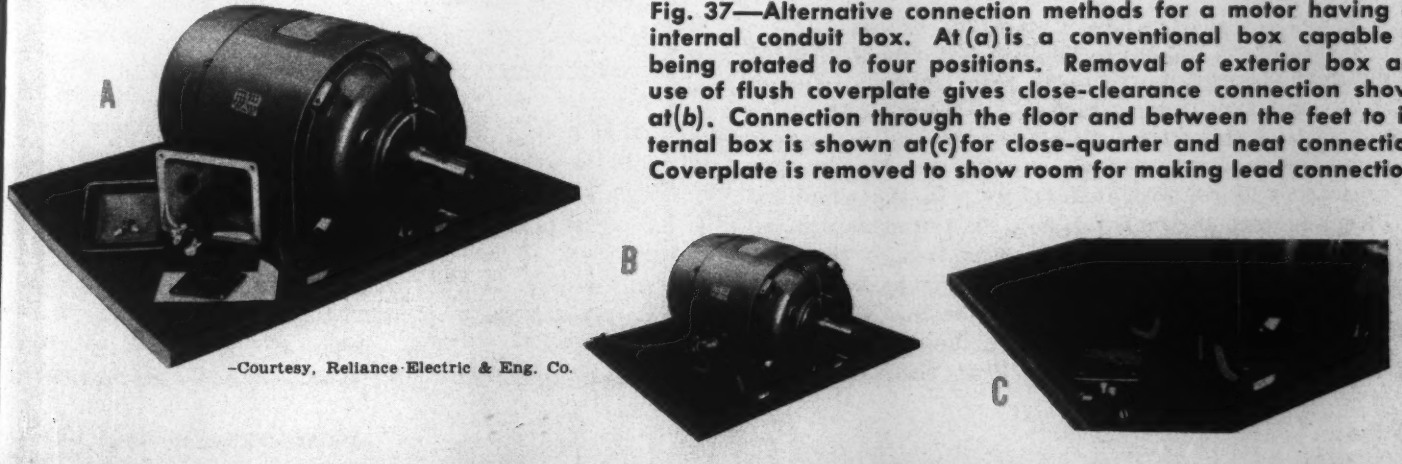
Installed on a can closing machine, *Fig.* 35, a 7½-horsepower, 2-speed, 1800/900 rpm brakemotor is capable of stopping the machine in one can cycle (within 1/5-sec), stopping automatically in case of jamming. The slower speed is employed for a short time during machine starting after which normal operation is at the higher speed.

One of the most unusual designs that have been developed for motor auxiliaries is the clutch-brake motor, illustrated in *Fig.* 36. This 1-horsepower, totally-enclosed (nonventilated) motor contains a magnetic clutch and brake. Both auxiliaries have stationary field windings, obviating slip rings. Through the ingenious use of materials and the novel utilization of the motor itself for flux paths, the motor is no larger than a standard motor. The sectional view in *Fig.* 36 shows these flux paths and how the coils are embedded in the motor frame. The motor armature is piloted by bearings on the motor shaft and runs continuously. In this arrangement the motor shaft can be accelerated or stopped quickly without involving the rotor Wr^2. Repeated and quick starts or stops may be effected without excessive motor heating. Designed as a loom motor where the inertia of the connected load is small, this motor may also be useful in special industrial fields where the duty cycle involves light loads.

Referring to *Fig.* 36, the clutch and brake rotors are both splined to a shaft hub and their mating armatures are fastened to the rotor and frame, respectively. When the clutch coil is energized, flux passes through the motor frame, the clutch armature, the rotor, the air gap, the stator and back to the frame, completing its path. The brake coil has a shorter path, being through the frame and the brake armature. The coils are energized with dc current and the brake is controlled automatically in case of thread breakage on the textile machine.

OTHER AUXILIARIES: Thermal overload protection, governors, and plugging switches function with respect to the electrical features of a motor. Thermal protection is usually an optional feature. On a fractional-horsepower motor its operation depends on a bimetallic element placed in the field windings of the motor so as to respond to both current and temperature. On integral-horsepower motors, the bimetallic element is usually responsive to temperature only. It thus protects the motor from excessive overload current, high ambient temperature and inability to start.

These devices are reset either manually or automatically, depending upon the kind of protection desired. Manual reset is employed where automatic restarting would be undesirable because of safety. Automatic reset is employed wherever restarting is



–Courtesy, Reliance Electric & Eng. Co.

Fig. 37—Alternative connection methods for a motor having an internal conduit box. At (a) is a conventional box capable of being rotated to four positions. Removal of exterior box and use of flush coverplate gives close-clearance connection shown at (b). Connection through the floor and between the feet to internal box is shown at (c) for close-quarter and neat connection. Coverplate is removed to show room for making lead connections

desirable when the motor has cooled. If the overload conditions persist the thermal device cycles, protecting the motor until the trouble is corrected. Because of the long reset time for large motors, provisions are sometimes made to allow the motor to run idle, increasing cooling to shorten the reset time.

Speed indicators are also frequently built into a motor as a convenient method of mounting when such an indication is desired.

In locations where humidity conditions are excessive and a motor is not in constant service, the moisture conditions might affect the motor insulation adversely. For such conditions it is usual to build in space heaters to prevent condensation. This protects the electrical insulation of the motor and eliminates the possibility of failure of the motor from this cause.

Accessories: On integral-horsepower motors, conduit boxes for connection to power sources are usually attached to the side of the frame on the vertical centerline of the motor feet and are capable of being rotated. When these boxes interfere with applications because of space requirements, the box may be specified for alternative locations. This problem has given rise to modifications in this feature by some manufacturers, these modifications being furnished as standard. As an example, in one arrangement, an internal conduit box provides for removal of the exterior box and substitution of a flush cover plate with a standard knockout. The internal box is mounted between the feet, requiring no additional clearance on the external diameter. Also, if desired, the electrical connections may be made through the bottom of the internal box, the conduit being between the motor feet and a flush cover plate. These three methods of connections for the same motor are shown in *Fig.* 37.

On small subfractional motors particularly, it is often advantageous to obtain motors with the leads in the position desired and of the length required for direct connection to control elements without intermediate wiring. Connectors may also be specified on the leads. When special lead lengths are required for direct-connection to external control elements it is necessary to determine the motor type and control desired, such as reversing, etc., in specifying the lead lengths and their number.

Frequently, on fractional-horsepower motors, a switch is available on the motor for on-off operation or even for reversing the motor. For the latter, a double-throw switch is supplied. When motors are supplied as stock, sometimes connection plugs are conveniently and neatly attached so that direction of rotation of the motor may be reversed by plug removal and reinsertion in a rotated position.

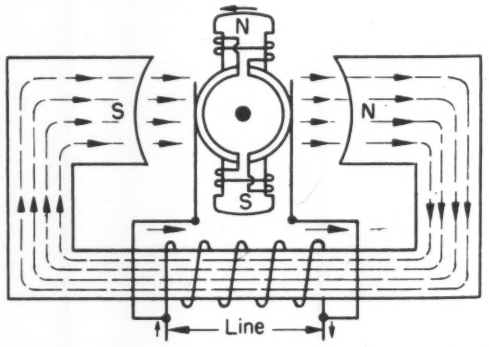
Electrical Characteristics.....

AS IN ALL DESIGN, electrical features of motors are the result of compromises. A specific motor may be designed, for instance, for minimum cost, minimum size or maximum efficiency. In each case the motor would be different from the other two. The proper motor, however, would be determined by the relative importance given to each of the controlling factors, depending on their relationship to the intended application.

Every type of motor, either ac or dc, has basic characteristics. These may be varied within certain limits but the family features remain. Starting current, starting torque, efficiency, breakdown or pullout torque, speed-torque relations, and speed characteristics over the operating range are distinct family attributes and will be discussed briefly for each type of motor.

What makes a motor run has been the subject of different theories, particularly with respect to single-phase and synchronous motors. Without getting involved in a theoretical discussion, generally accepted principles on how rotational torques are developed in a motor will be presented briefly. In the simplified direct-current shunt motor, *Fig.* 38, the armature coil is shown connected in parallel with that of the field. The current flow in the field coil is such as to produce magnetic poles on the stator as shown. Current is also flowing in the armature coil, the direction being controlled by a commutator. With the coils in the position shown, the flux surrounding the wire (resulting from its current flow) produces magnetic poles on the armature. Because unlike poles attract and like poles repel, a torque is produced in the direction shown. As the armature poles reach the position of the field poles, the commutator segments in contact with the brushes reverse their contacts, reversing the current flow in the armature. This reverses the polarity of the armature, continuing the rotational torque in the same direction.

Fig. 38—Schematic representation of a shunt dc motor showing how electro-magnetic forces act on a motor to produce rotational torque



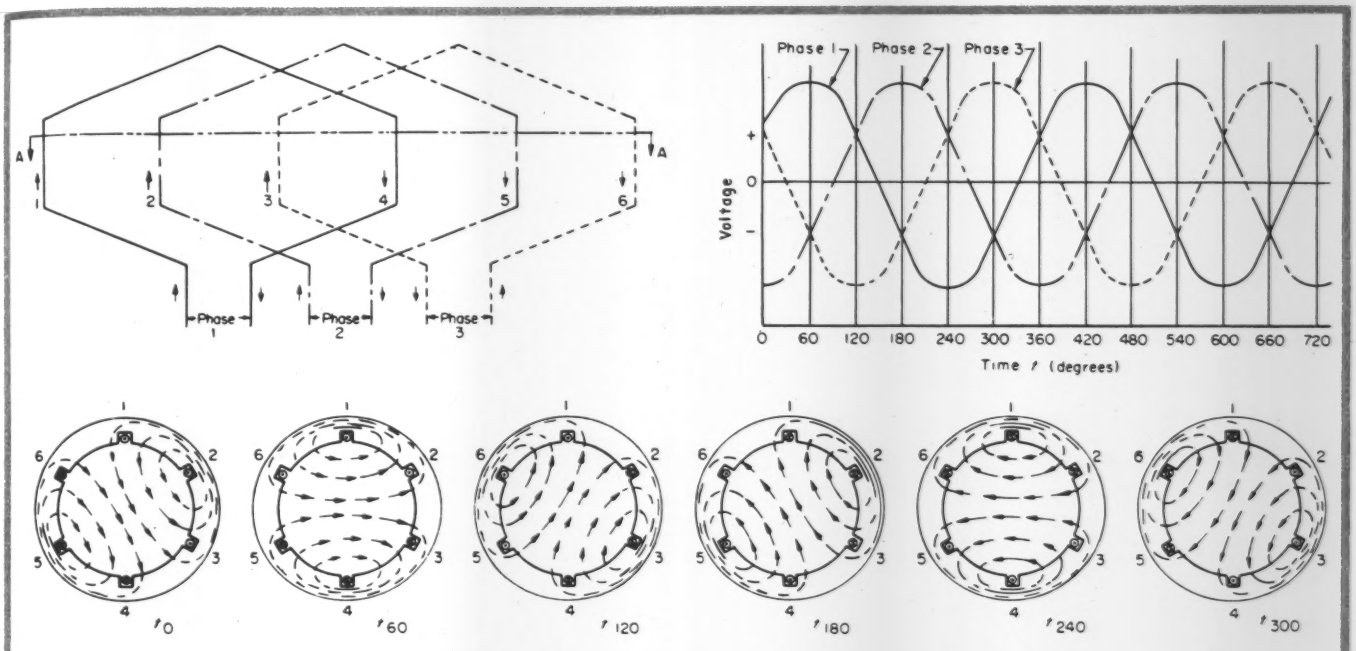


Fig. 39—Principle of a 3-phase induction motor showing phase sequence of current supply to the motor field which is laid out flat and sectioned at *A-A* to show effect of current reversals to produce a rotating field

To determine polarity produced by a coil, the simple right-hand rule is helpful. By imagining the conductor grasped with the right hand in such a way that the thumb points in the direction of current flow, the fingers circling the conductor point to the direction of the magnetic flux encircling the conductor.

The direction of this encircling flux on the side of the coil core determines the direction of the magnetic flux in it. In this case the core flux is from right to left with the current flowing in the direction shown, making the right and left poles of North and South polarity, respectively. The same rule is helpful in determining the direction of force on a conductor carrying current in a magnetic field. This force is in the direction away from and normal to the point where the two fluxes are parallel and in the same direction.

Whether the armature and field coils are connected in series, in parallel, or in a compound combination of both, the forces acting on the armature coils to produce rotation are similar. Also, in a universal motor, which is designed for operation on either alternating-current or direct-current power supply, the action may be likened to that shown in *Fig.* 38.

With alternating current, the instantaneous forces at any current-phase position (other than zero current) are the same when the current is flowing in the direction shown. At the time of cycle reversal, the current flow reverses in both the armature and field coils to continue producing the rotational torque in the same direction. To obtain reversal of direction of rotation, the current flow either in the armature or in the field is reversed. This reverses the torque reaction, reversing the motor.

In a dc motor, the armature is wound with successive coils which progressively have current flowing in the proper direction as the commutator segments to which the coil ends are attached come into position, producing rotational torque. In alternating-current induction motors, however, the pulsing current reversals in the field windings, produce an imaginary rotating magnetic field. Currents in the armature bars induced by the flux of this rotating field cause the armature to follow the field but at a speed somewhat below that of the field called the synchronous speed. The per cent difference between these speeds is known as slip. Through this slip the motor torque is developed. It increases with the slip up to the breakdown torque of the motor.

To show how a rotating field is produced in a motor, a 3-phase alternating-current supply is flowing in the developed or laid-out-flat windings in the sketch of *Fig.* 39. Phase 1 of the current is flowing in the solid-line winding. Phase 2 in the dash-line winding and Phase 3 in the dotted-line winding. The current flow in each winding reverses with each cycle reversal for each phase. To indicate field rotation in the counterclockwise direction for the system being illustrated, the windings are shown sectioned at A-A for six 60 electrical degree positions corresponding to t_0, t_{60}, t_{120}, and t_{180}, t_{240}, and t_{300}. It will be noted that t_{360}, etc., corresponds respectively, to t_0, etc. The degree positions are electrical degrees determined by the power supply, 360 degrees being a complete current cycle. In this case the motor is a two-pole design and the mechanical degree positions of the motor field correspond to the electrical degrees, as will be shown. Thus in a 60-cycle system the field rotation would be 3600 rpm.

At time t_0, current is flowing in the field windings in the direction shown. In section *A-A* this current

flow is represented as dots when the current is approaching and as crosses when it is receding. Each conductor carrying current has a magnetic field which rotates counterclockwise in conductors carrying approaching current and clockwise for receding current. The right-hand rule also shows the direction in this case. The flux therefore, for the conductors shown, flows upward through the air gap and returns through the stator core to complete its path. At time t_0, current is flowing in the "flat" windings and in section *A-A* as shown producing a magnetic field.

In this way the field has a definite counterclockwise direction of rotation which the rotor follows at a reduced speed, resulting from the current induced in its windings or short circuited bars along the surface of the rotor. This reduced speed is known as slip and is characteristic of induction motors. The slip induces current flow in the rotor and the resulting reaction causes the rotor to follow the field by the reaction of the flux from the induced current. This accounts for reduction in speed with increased load in an induction motor, making it actually produce more torque as the load increases up to the torque limit.

In a single-phase system, however, there is no distinct rotational field, in other words, the field seems to rotate simultaneously in both clockwise and counterclockwise directions. This is the reason that single-phase motors require additional starting methods to add a simulated phase shift to give direction to the field, approaching the effect of the rotating field of a two-phase motor. This phase shift is accomplished by an auxiliary starting winding with its electrical phase shifted with respect to the main field winding by a capacitor, impedence or other method. Usually, a centrifugal switch is employed to disconnect the starting winding after the rotor reaches sufficient speed to follow one direction of the rotational field produced by the main windings.

As indicated, an induction motor cannot run at synchronous speed, but operates at some differential percentage of slip depending upon the load and the electrical design of the motor. If it were to run at synchronous speed, no torque would be developed because the windings or bars on the rotor would not be traversed by the field flux and no current would be induced in the rotor.

Synchronous motors differ markedly in design and operational characteristics from other forms of motors. When running as a synchronous motor, the motor will maintain its synchronous speed exactly without slip. Any load sufficiently high to cause loss of synchronism will stall the motor. This load is known as the pull-out torque. The rotor of a synchronous motor has salient or distinct poles, maintaining their polarity while running.

It is impossible for a synchronous motor to start itself without being driven or having its rotor connected in the form of a self-starting motor. It cannot start itself because the field is rotating at synchronous speed and the motor must be accelerated before it can pull into synchronism.

A rubber-band analogy may be applied to synchronous motors. Consider the rotational field and the rotor connected physically by short lengths of rubber bands that cannot stretch more than half the distance to the following field pole. With any driven load, the field would drag the rotor after it at the same specific speed. If an added load were put on the motor, the bands would stretch to balance the load but the rotor would still follow at the same speed except during the momentary shift in relative position. This shift would continue with increasing load until the overload condition is reached, breaking the rubber bands. The motor then stalls. In a synchronous motor, this displacement is known as angular lag and is proportional to the load almost up to the pull-out torque where the lag increases rapidly until the pull-out torque is reached.

Speed: Nominal speed or full-load speed of ac motors is determined by the frequency, f, in cycles per second, the number of poles, N, in the motor and the percentage slip, s, designed into the motor. Universal motors, however, are excepted from this proportionality because they are designed and behave like dc motors of the series type. The speed of all ac motors is

$$S = \left(\frac{100 - s}{100}\right) 2\,\frac{60f}{N} \text{ rpm}$$

Since there is no slip in synchronous motors ($s = 0$), the slip expression in the foregoing equation drops out. Speed of these motors, revolving at exactly the same speed as the imaginary magnetic field, varies directly as the frequency and inversely as the number of pairs of poles.

Slip in general-purpose ac motors is from 3 to 5 per cent, depending on the inherent characteristics designed into the motor. For polyphase motors, both induction and wound-rotor types, speeds are rated in percentage slip, using the synchronous speed as a reference speed. Some polyphase definite-purpose and special-purpose motors may have slip values higher than 5 per cent. Known as Design *D* motors, they may be applied for starting high inertia loads, reducing peaks of current input, etc.

Speeds of dc motors are dependent on their design characteristics and may be varied or adjusted by altering the voltage on the armature or field or both. These features and their controls will be discussed in the sections on dc motors and applications.

Ability of a motor, either ac or dc, to maintain relatively constant speed over its operating range is a measure of its usefulness for many applications. A universal criterion for indicating this quality of a motor is known as *speed regulation* and is defined as the change in speed from no-load, S_n, to full-load, S_f, conditions, expressed as a percentage of full-load speed. Thus, the speed regulation of any motor is

$$R = \frac{S_n - S_f}{S_f}\,100$$

Since a synchronous motor operates at synchronous speed over its entire range, its speed regulation is 0 per cent. Regulation of a general-purpose ac motor having good speed characteristics is about 4 per cent. In dc motors, however, there is no slip value for comparison. A dc shunt motor speed regulation is in the neighborhood of 10 to 20 per cent. Compound motors

are 20 to 40 per cent. Series motors, having runaway characteristics at no load, are not usually rated for speed regulation. Theoretically, neglecting friction, windage, etc., speed regulation would be infinite.

Rotation: Direction of rotation may cause confusion insofar as specification is concerned. This stems from the definition of the "front" end of a motor. The front, by definition, is the end opposite the drive end or shaft extension. For all motors (other than polyphase) that are nonreversing, standard rotation is counterclockwise when viewed from the motor front. To many, it is more natural to view the motor from the drive end and to regard standard rotation as clockwise. Care must therefore be exercised in specifying direction according to standard definition. Unless otherwise specified, nonreversing single-phase motors are connected for standard direction of rotation. Polyphase induction motors, however, depend on their connections to the power supply to determine their direction of rotation. Probably, the historical reason for naming the front end of a motor is because the leads, brush holders, and commutators or slip rings are located at that end.

Current: All ac motors regardless of type or size are designed for across-the-line starting, i.e., full voltage applied to the motor at rest. On large motors or in systems where the higher starting current would affect other electrical equipment adversely or would be objectionable otherwise, reduced-voltage starters are employed. These lengthen the time of acceleration by reducing the available torque during starting. In starting dc motors, the limiting condition is commutation. Small motors up to 5 horsepower have been built capable of being linestarted. For larger motors, starting current peaks are limited to 250 per cent of full-load current, and less as the size increases.

Full-load current for all types of motors is shown in TABLE 13. These values are approximate and are grouped for single-phase, three-phase and dc motors from ½ to 40 horsepower. Because this table has been compiled from representative motors, variations of 10 per cent above or below the given values may be expected.

Standard ac motors, except polyphase wound-rotor motors, have a nameplate "Code" letter designation to indicate the locked-rotor kva per horsepower as listed in TABLE 14. These values are measured at rated voltage and frequency. Multispeed motors are rated for the highest speed except constant-horsepower motors which are rated at the highest value. Dual-voltage motors are also rated at the highest value. Motors for 50-60 cycles are rated for 60-cycle duty.

Multispeed motors: When two or more speeds are desired from an induction motor, leads from the stator winding are brought outside the motor for external connections to the controls. When two speeds are desired, having a ratio of 2:1, the windings may be reconnected simply to double the number of poles, using one set of windings. If more than two speeds are desired or if the speed ratio is not 2:1 for two speeds, the stator is wound with two or more separate windings, each of which may have the two speed con-

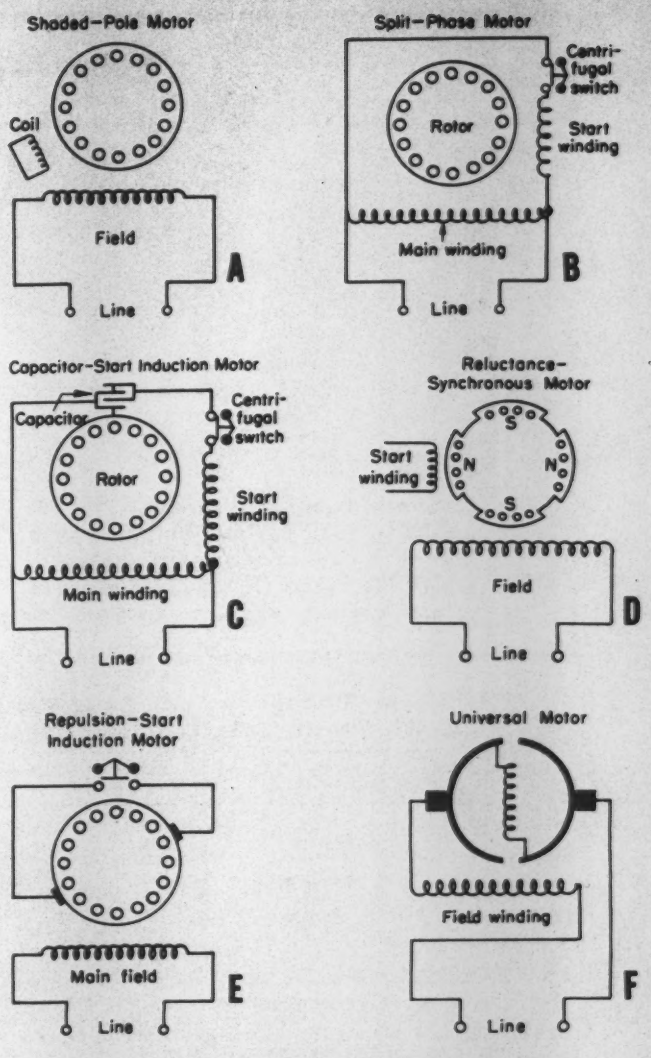


Fig. 40—Six basic types of single-phase motors, showing schematically their principal features

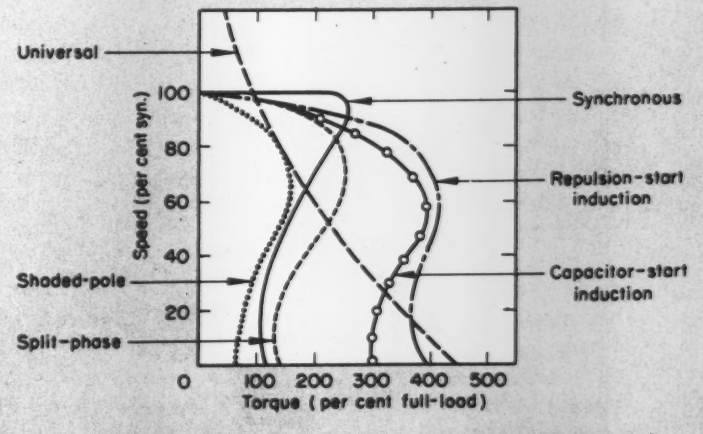


Fig. 41—Speed-torque curves for single-phase motors plotted against full-load torques and speeds. No-load and full-load torques for split-phase, capacitor-start and repulsion-start motors are identical because motors operate as induction type. Wide variations in starting torques are apparent

Table 13—Approximate Full-Load Current*†

Motor Rating (hp)	Direct-Current Motors			Single-Phase Motors§		3-Phase Squirrel-Cage Motors§				3-Phase Wound-Rotor Motors§			
	115-volt (amp)	230-volt (amp)	550-volt (amp)	110-volt (amp)	220-volt (amp)	110-volt (amp)	220-volt (amp)	440-volt (amp)	550-volt (amp)	110-volt (amp)	220-volt (amp)	440-volt (amp)	550-volt (amp)
½	4.5	2.3	...	7	3.5	5.0	2.5	1.3	1.0	...	...	...	...
¾	6.5	3.3	1.4	9.4	4.7	5.4	2.8	1.4	1.1	7.2	3.6	1.8	1.5
1	8.4	4.2	1.7	11	5.5	6.6	3.3	1.7	1.3	7.8	3.9	2.0	1.6
1½	12.5	6.3	2.6	15.2	7.6	9.4	4.7	2.4	2.0	...	...	...	...
2	16.1	8.3	3.4	20	10	12.0	6	3.0	2.4	14.4	7.2	3.6	2.9
3	23	12.3	5.0	28	14	...	9	4.5	4.0	20.2	10	5.0	4
5	40	19.8	8.2	46	23	...	15	7.5	6.0	...	15	7.5	6
7½	58	28.7	12	68	34	...	22	11	9.0	...	25	13	10
10	75	38	16	86	43	...	27	14	11	...	28	14	11
15	112	56	23	...	...	...	38	19	15	...	45	23	18
20	140	74	30	...	...	...	52	26	21	...	56	28	22
25	185	92	38	...	...	...	64	32	26	...	67	34	27
30	220	110	45	...	...	...	77	39	31	...	82	41	33
40	294	146	61	...	...	...	101	51	40	...	106	53	42

* Courtesy, Fairbanks, Morse & Co.
† Values are approximate, being averages of representative motors. Variations of plus or minus 10 per cent may be expected.
§ For 60-cycle motors.

Table 14—Nameplate Code Designations on AC Motors for Locked-Rotor Kva†

Letter Designation	Kva per Horsepower*
A	0–3.15
B	3.15–3.55
C	3.55–4.0
D	4.0 –4.5
E	4.5 –5.0
F	5.0 –5.6
G	5.6 –6.3
H	6.3 –7.1
J	7.1 –8.0
K	8.0– 9.0
L	9.0–10.0
M	10.0–11.2
N	11.2–12.5
P	12.5–14.0
R	14.0–16.0
S	16.0–18.0
T	18.0–20.0
U	20.0–22.4
V	22.4–up

† From NEMA Standards.
* Locked kva per horsepower range includes the lower figure up to, but not including, the higher figure. For example, 3.14 is designated by letter A and 3.15 by letter B.

—Courtesy, NuTone Inc.

Fig. 42—Ceiling electric heater and light unit utilizes a Redmond 1/70-horsepower enclosed shaded-pole motor to drive a fan. Control is simple and motor is inexpensive

nections. Four speeds, however, is the practical limit for economical performance.

In TABLE 15 are listed types of motors built by various manufacturers, showing horsepower, speed and voltage ranges for each type of motor. Also included are enclosures normally available, as well as built-in auxiliaries such as gearing, brakes, multi-speed windings, and thermal protection. Inasmuch as this tabulation includes ranges of motor features and characteristics, it should not be presumed that the upper and lower limits of one column, for instance, apply to the whole range in another column. Likewise, the enclosure and auxiliaries do not necessarily apply to all motors tabulated as available as standard. Instead the listing shows the extent to which each manufacturer specializes in each group.

Service Factor: General-purpose motors are usually designed for continuous overload operation without overheating at rated voltage and frequency. The overload ratio which may be safely applied to a given motor is called the service factor. For fractional-horsepower motors this factor may range from 1.4 to 1.25 with the higher values applying to the smaller ratings. For integral-horsepower motors the factor may range from 1.25 to 1.15. Above 3 horsepower, the standard service factor is 1.15.

Single-phase motors: Because the majority of applications for small motors are for commercial, business and domestic uses where polyphase power is seldom available, single-phase motors are built in large quantities, exceeding those for polyphase service. This does not mean that single-phase motors are superior. As a matter of fact they are generally inferior with respect to both starting and power characteristics, the general availability of the power being the determining factor.

There are six basic types of single-phase motors, each having variations in electrical design. These types include: Shaded-pole, split-phase, universal, capacitor, repulsion-start, and synchronous motors. All the designs other than universal are primarily concerned with features to develop starting torques.

With the exception of the universal, synchronous and special forms of repulsion motors, they all run as induction motors. To illustrate the basic differences in these motors, the schematic sketches in *Fig.* 40 show the basic design principles of each.

As indicated in *Fig.* 40, the shaded-pole motor is characterized by short-circuited coils connected permanently in slots in the edge of each field pole. The split-phase motor is recognized by an auxiliary starting winding connected into the power circuit through a centrifugal switch. The capacitor motor, of which there are three types, is illustrated in *Fig.* 40 as a capacitor-start induction run. This form, being the most common, resembles the split-phase motor with a capacitor added in series with the starting winding. Each of these motors have squirrel-cage rotors, i.e., skewed bars on the cylindrical surface which are short-circuited at both ends.

Synchronous motors, *Fig.* 40, have various types of starting windings and are identified by salient poles on the rotor. For repulsion motors, the repulsion-start induction-run type is illustrated. It has a commutator and short-circuited brushes as shown. After starting a centrifugal switch either lifts the brushes or opens the brush circuit, permitting the motor to run as an induction motor with a squirrel-cage rotor.

Universal motors, *Fig.* 40, have wound rotors, commutators and brushes. In this type of motor, the field windings are series-connected with the rotor. The electrical circuit is similar to a direct-current series motor, the difference being that the current characteristics are designed so that the motor operates substantially the same on either ac or dc current. For this reason the motor is called universal. In operation, however, the speed and efficiency tend to be somewhat higher for dc operation.

Comparative speed-torque curves showing average characteristics for these motors are plotted in *Fig.* 41. These values, of course, only show generally the characteristic shape of the torque curves.

Nominal full-load speeds have been assigned to fractional-horsepower induction motors according to the type of motor and frequency of the power supply. For 60-cycle current, the approximate full-load speeds are listed in TABLE 16. Similarly, proportional values have been assigned to 50-cycle power and, for 2-pole motors, to 25 cycles. Other than synchronous motors, single-phase motors are classified according to their torque characteristics as either Design *L* or Design *M*. Minimum values of starting torque, breakdown torque and starting current are assigned to these motors, Design *L* having higher starting current values than Design *M*.

Single-phase induction motors are rated primarily on their breakdown torques, the highest loads at which the motor characteristics are stable. Minimum values of breakdown torques for 2, 4 and 6-pole 60-cycle motors are tabulated in TABLE 17. Actual breakdown torques may be any value up to the next horsepower rating. Starting torques have been standardized for fractional-horsepower motors above ⅛-horsepower and are shown in TABLE 18 for 60-cycle power. These are minimum values based on locked-rotor conditions. Maximum current values, regardless of the number of poles in a motor are also shown in TABLE 18. Motors smaller than 1/6-horsepower should not have starting currents in excess of that shown, namely, 20 amp at 115 volts.

—Courtesy, Barber-Colman Co.

Fig. 43—Open view of draftsman's and stenographer's eraser, showing skeleton type shaded-pole motor. Economical design provides recess in molded case to enclose motor

SHADED-POLE MOTORS: This type of motor is popular for driving loads having low starting torques such as fans, *Figs.* 42 and 43. Shaded-pole motors are particularly desirable for such applications, operate quietly, and are the simplest of the single-phase motors, requiring no centrifugal or switching devices for starting. The only moving parts are the rotor and shaft. Because of low starting torque and efficiency, they are used only in small sizes (below ⅛-horsepower) where power consumption is an unimportant factor. Often, they are employed as torque motors because they can be stalled for extended periods without overheating.

Available in sizes up to ⅛-horsepower in 2, 4 and 6-pole construction, the shaded-pole motor is characterized by a slot in each field-pole face in which is placed a short-circuited ring of copper or other conductor. This provides an auxiliary phase shift to develop a rotating field in the direction toward the shaded coils, giving the motor its starting torque. These motors may have a tapped main winding or an additional skein winding for speed control.

Because the shading coils remain in operation while the motor is running, efficiency is lower than for other types of motors. A shaded-pole motor should always be applied at or near its full-load rating. Its efficiency increases with the load and speed decreases slightly, and it is a fairly constant-speed motor. Typical power, speed and efficiency curves are plotted against torque in *Fig.* 44 for a 1/125-horsepower motor.

Cutaway view of a shaded-pole motor, showing its internal construction is illustrated in *Fig.* 45. This is a totally-enclosed motor with 6 poles and is rated

—Courtesy, Bodine Electric Co.

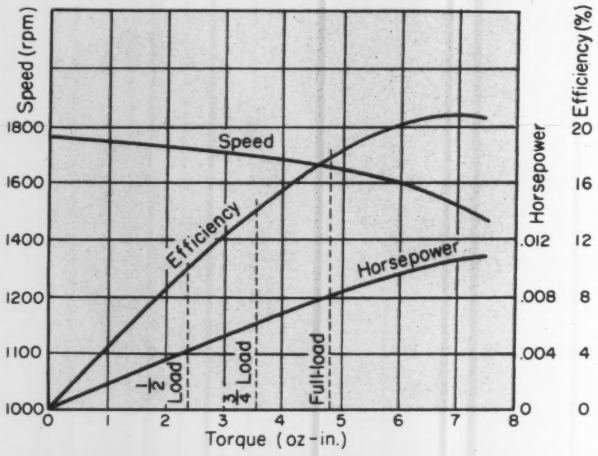
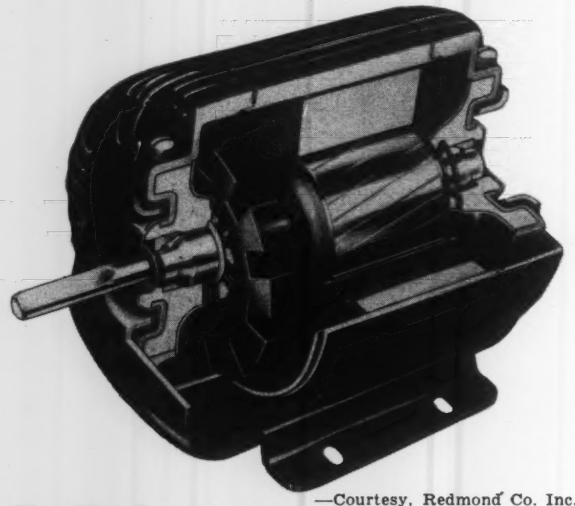
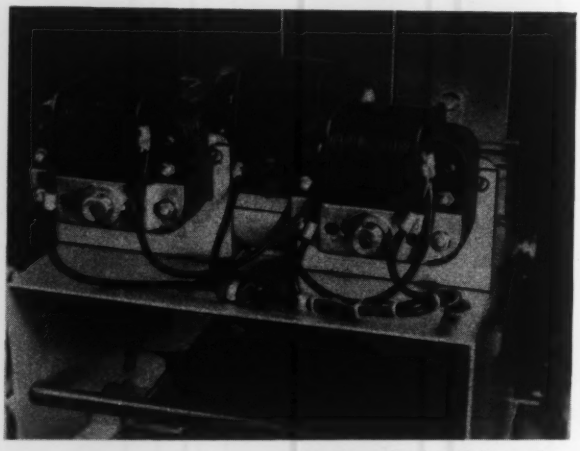


Fig. 44—Typical characteristic curves for a shaded-pole motor rated at 1/125 -horsepower



—Courtesy, Redmond Co. Inc.

Fig. 45—Cutaway view showing construction of a shaded-pole motor. This motor, rated at 1/20-horsepower is totally enclosed, having external fins for heat dissipation



—Courtesy, Barber-Colman Co.

Fig. 46—Three skeleton type shaded-pole gearmotors driving screws for dispensing coffee, cream and sugar in a vending machine

at 1/20-horsepower. It measures 4⅝ inches in diameter and has an internal fan for circulating the air within the motor to assist in dissipation of heat through the outer fins. The same motor with an open-ventilated enclosure would be rated at 1/15-horsepower.

In *Fig.* 46 are three skeleton type shaded-pole gearmotors driving feed screws in a coffee vending machine. For this application, inexpensive, compact and dependable motors are required. The motors have open type gear reductions and are rated at 0.0065-horsepower for intermittent duty cycles.

Because shaded-pole motors have short-circuit coils, usually consisting of one turn of heavy wire to shade one side of each field pole, they are classified as unidirectional motors and will rotate only in the direction toward the shading coils. There are, however, special forms of shaded-pole motors that are reversible. The shading coils are wound of fine wire and are placed on each side of each field pole. The coils are arranged so that they may be cross connected to reverse the direction of rotation. For a two-pole motor, with two shading coils on each pole, a single-pole double-throw switch controls the pair of coils which are short circuited as shown in *Fig.* 47*a* to reverse the direction of rotation. In these subfractional-horsepower motors designed for continuous duty, the motors may be cycled frequently without overheating.

There is inherent dynamic braking in these motors when the shading circuit is opened, caused by the generator action in the squirrel-cage rotor. With the field continuously energized, an alternating-current field threads the rotor. Thus, opening the shading circuit while the motor is running sets up induced currents in the rotor which react with the magnetic field of the stator. This stops the motor in less than one second with no load on the motor. More effective dynamic braking is obtained by shorting both pairs of shading coils at once. In other words, while one pair is shorted with the motor running in one direction, shorting the other pair stops the motor almost instantaneously.

In a reversible shaded-pole motor, efficiency is sacrificed because of the inactive shading coils, reducing the flux path across the field. Efficiency usually is of little concern in the miniature sizes in which these motors are built. They are highly satisfactory for operating small valves, dampers, etc., and also are useful in servo applications because of simplicity of control and the low inertia of the rotor for positioning and rapid reversal. For instance, motors in the 0.0001 to 0.03-horsepower sizes have inertias in the range from 0.0024 to 0.0385 lb-in.^{2} Also, these motors sacrifice about 25 per cent of their starting torque when designed for reversing service.

Referring again to Fig. 47*a*, if a capacitor is connected in the outside branch of the shading circuit, the phase relation of the shading current is improved, increasing the torque and power available. This system, however, is not practical when low-voltage shading coils are employed. Instead of using the double-throw switch in *Fig.* 47*a*, a single pole switch may be used if a resistance is used in series with one pair of

shading coils as shown in *Fig. 47b*. This resistance is chosen to produce about 50 per cent of normal torque. Although the switching is simplified it should be noted that 50 per cent of the motor torque is sacrificed.

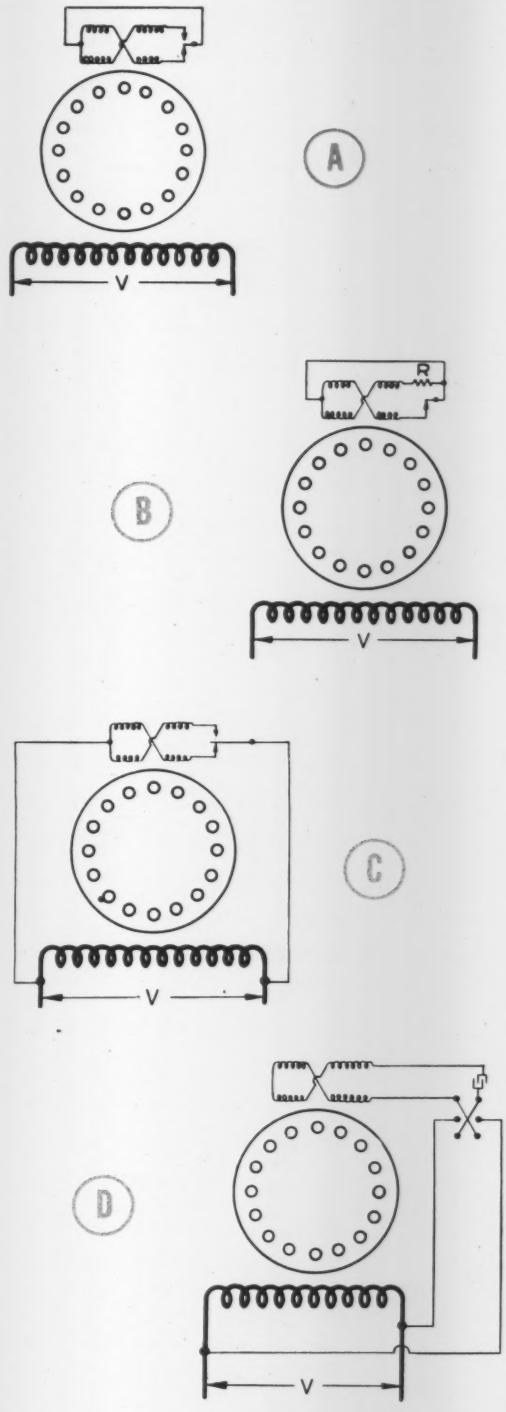
It is also interesting to note that the shading coils in *Fig. 47a* may be connected in parallel with the field coil as indicated in Fig. 47*c*. Instead of sacrificing efficiency, this system of reversing a motor increases torque as much as 25 per cent over standard shaded-pole operation and, in addition, provides dynamic braking for either direction of rotation when the switch is in neutral position. A capacitor added to the shading coil circuit may increase the torque available as much as 40 per cent. When a double-pole double-throw switch is employed in the shading circuit so that all four shading coils remain in the circuit, and a capacitor is used, the developed torque may be three times that of normal shaded-pole operation. This system is illustrated in *Fig. 47d* and supplies dynamic braking. The capacitor may be omitted for connection to two phases of a three-phase power supply to give similar characteristics. If, in single-phase applications, electronic tubes are employed to operate the shading coils 90 degrees out-of-phase with the field coils, the motor operates as a 2-phase motor and develops 3 times the normal power.

Although starting torques of shaded-pole motors are relatively low, special designs may develop a higher starting than running torque. This is usually accomplished by using rectangular instead of round bars in the squirrel-cage rotor. Synchronous motors are also of the shaded-pole motor type. These motors start as shaded-pole motors and, when they pull into synchronism, operate as reluctance motors. These will be discussed more fully under synchronous motors.

Record-player turntable drives, *Fig. 48*, employ shaded-pole motors, usually driving the turntable rim by friction pulleys. Constant speeds are obtained because the loading is constant. To avoid wow and distortion, the friction drive elements are carefully ground to concentricity. In the drive illustrated, a two-pole motor drives one of three turret pulleys which in turn drive the idler wheel contacting the inside rim of the turntable. The two pulleys not in contact with the idler remain stationary.

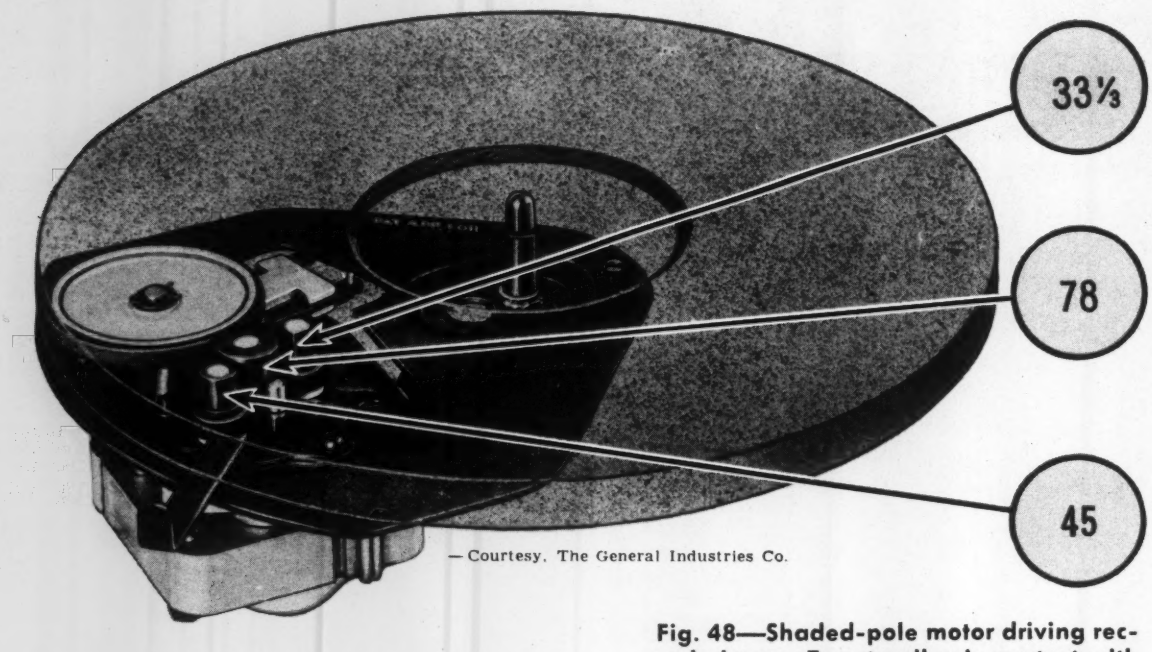
SPLIT-PHASE MOTORS: These induction motors have fairly constant speed over their operating range from no load to about 50 per cent overload. Starting torque is about twice full-load torque and breakdown torque is about 2.5 times full-load torque. Efficiency of operation improves with increased load and reaches 50 to 55 per cent at full load, increasing to about 60 per cent at 50 per cent overload. These characteristics are, of course, typical and may be modified by design within limits.

Power losses are practically constant over the operating range up to full-load conditions whereupon the current input begins to rise, increasing markedly as the load approaches the breakdown torque. These power losses are, of course, converted to heat, and continued operation at overload conditions above 150 per cent would result in overheating. Inasmuch as power losses are constant up to full load, the heat



—Courtesy, Barber-Colman Co.

Fig. 47—Special connections for shaded-pole motors, utilizing wound shading coils for reversing duty and for improving characteristics. At (*a*) four shading coils are connected by a switch to short alternate coils for reversing the motor. The same effect is obtained at (*b*) by using a resistor for the reversing coils. When coils are shunt connected as at (*c*) performance of reversing motor is greatly improved. When cross-connected with a capacitor in series as at (*d*) performance is further improved



—Courtesy, The General Industries Co.

Fig. 48—Shaded-pole motor driving record player. Turret pulley in contact with idler wheel determines turntable speed

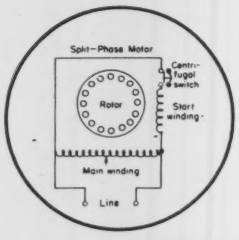


Fig. 49—Typical speed-torque curves for a 1/10-horsepower split-phase motor showing current, speed efficiency and power factor plotted against torque

—Courtesy, Lamb Electric Co.

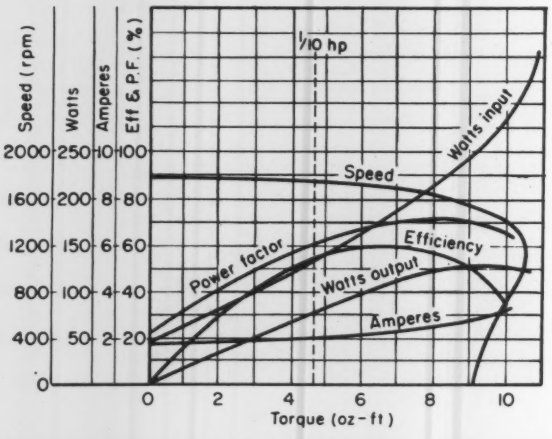
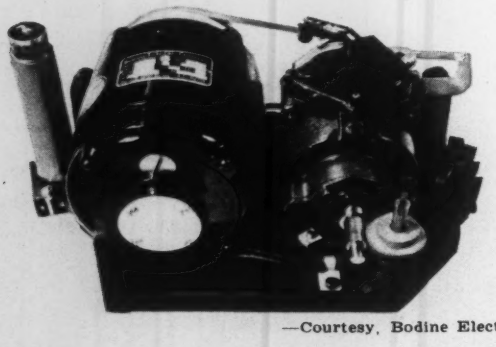


Fig. 50—Totally enclosed, 1/15-horsepower split-phase motor drive for a high-speed camera



—Courtesy, Bodine Electric Co.

TABLE 15

Table 15

MANUFACTURER OF MOTOR TYPES[1]	FEATURES (Code)[2]	MOUNTINGS (Code)[3]	TYPES OF ENCLOSURES (Code)[4]	SHADED-POLE (hp)	SHADED-POLE (rpm)[5]	SHADED-POLE (volt)	SPL (hp)	SPL
Alliance	T	E	O	1/400--1/25	1550--2800	24--235	.....	..
Allis, Louis	B-G-M-T	E-F-P	O-D-S-W-N-V-X	.....	.....	.....	.....	..
Allis-Chalmers	G-M-T	E-F	O-D-S-N-V-X	.....	.....	.....	.....	..
Baldor Electric	M	E-F	O-D-S-W-N-V-X	.....	.....	.....	1/12--1/3	12
Barber-Colman	B-G	E-F	O-N-V	.0001--.032	1000--3000	115	.....	..
Bodine	B-G-T	E-F-P	O-D-S-N-V	1/250--1/150	1600	115-230	1/150--1/6	11
Brown-Brockmeyer	G-T	E-F	O-D-S-W-N-V-X	.....	.....	.....	1/6--1/3	12
Century	G-M-T	E-F-P	O-D-S-W-N-V-X	.....	.....	.....	1/20--1/2	90
Crocker-Wheeler	B-G-M	E-F-P	O-D-S-N-V-X	.....	.....	.....	.....	..
Delco	M-T	E-F	O-D-W-N-V-X	1/250--1/80	1100--1500	115-230	1/6--1/3	12
Diehl	M	E-F	O-D-S-W-N-V-X	.001--1/20	250-2850	115--220	.....	..
Doerr	G-M-T	E-F-P	O-D-S-N-V	.....	.....	.....	.....	..
Electric Indicator	M-T	E-F	O-N-V	.....	.....	.....	Up to 1/10	60
Electric Motor	G-T	F	O-N-V	1/2000-1/15	1700	115	1/500--1/15	17
Electric Specialty	M	E-F	O-D-W-N-V	.....	.....	.....	1/6--1/3	18
Electro Dynamic	M	E-F	O-D-S-W-N-V	.....	.....	.....	.....	..
Emerson	T	E-F	O-D-S-N	.....	.....	.....	1/20--1/3	11
Fairbanks Morse	B-G-M-T	E-F-P	O-D-S-W-N-V-X	.....	.....	.....	.....	..
Fasco	G-T	E-F	O-D-N-V	1/1000--1/8	1000--3200	110--220	.....	..
Forbes & Myers	M	E-F-P	O-N	.....	.....	.....	.....	..
General Electric	B-G-M-T	E-F-P	O-D-S-W-N-V-X	1/500--1/20	1550--3000	115--230	1/20--1/3	86
General Industries	G-M-T	E	O-S-N-V-	1/500-1/50	1450--3500	24--230	.....	..
Heinze Electric	.....	E-F-P	O-N-V	1/750--1/50	1550--3100	115--230	.....	..
Holtzer-Cabot	G-M-T	E-F	O-N-V-X	.....	.....	.....	1/12--3/4	86
Hoover	T	E-F	O-D-N-V	.....	.....	.....	1/4--1/3	11
Howell	G-M-T	E-F	O-D-S-W-N-V-X	.....	.....	.....	.....	..
Jack & Heintz	T	E-F-P	O-D-S-W-N	.....	.....	.....	1/8--1/3	17
Janette (§)	B-G-M	E-F	O-N-V-X	1/150--1/20	1600	115	.....	..
Lamb Electric	G-T	E-F	O-D-S-W-N-V-X	1/150--1/25	1550-1600	115	1/20--1/8	11
Lear	B-G-T	E-F-P	V-X	.....	.....	.....	.....	..
Leece-Neville	G	E-F	O-D-W-N-V-X	.....	.....	.....	.....	..
Leland	T	E-F-P	O-D-S-N-V-X	.....	.....	.....	1/20--1/3	86
Lima Electric	B-G-M	E-F-P	O-D-N-V-X	.....	.....	.....	.....	..
Marathon	M-T	E-F-P	O-D-S-W-N-V-X	.....	.....	.....	1/20--1/3	86
Marco	T	E-F-P	O-D-S-W-N-V	1/100--1/8	1050--1600	110--230	1/30--1/4	11
Master Electric	B-G-M-T	E-F	O-D-S-W-V-N-X	.....	.....	.....	.....	..
Ohio Electric	T	E-F-P	O-D-W-N	.....	.....	.....	1/50--1/4	12
Oster	B-G-T	E-F-P	O-N-V-X	Up to 1/100	3500--10000	115--230 †	Up to 1/10	11
Peerless	T	E-F-P	O-D-S-N	.....	.....	.....	.....	..
Pesco	B-G	E-F-P	O-W-N-V-X	.....	.....	.....	.....	..
Rae Motor	B-G	E	O-D-N-V	.....	.....	.....	.....	..
Redmond	B-G	E-F	O-D-N-V	1/500--1/10	1000--3000	115--230	.....	..
Reliance	B-G-M-T	E-F	O-D-S-W-N-V-X	.....	.....	.....	.....	..
Reuland	M	E-F-P	O-D-S-W-N-V-X	.....	.....	.....	.....	..
Reynolds (Reco)	G	E-F	O-S-V	1/40--1/15	1680	115--230	.....	..
Robbins & Myers	M-T	E-F-P	O-D-S-N-V-X	1/250--1/8	1200--3600	115--230	1/20--1/3	90
Scruggs	.....	.....	O-N-V	1/50--1/200	1750	110--220	.....	..
Signal Electric	G	E-F	O-N-V	1/500--1/10	1100--2400	110--230	.....	..
Smith	T	E-F-P	O-D-N-V-X	.....	.....	.....	1/6--1/3	11
Star-Kimble	B-G-M	E-F-P	O-D-S-W-N-V-X	.....	.....	.....	1/2--5	72
Sterling	G-M	E-F	O-D-S-N-V	.....	.....	.....	.....	..
U.S. Electric	B-G-T	E-F	O-D-S-W-N-V-X	.....	.....	.....	.....	..
Universal	M-T	E-F	O-D-S-W-N-V	1/500--1/8	800--3200	24--230	.....	..
Valley	M	E-F	O-D-S-N-V	.....	.....	.....	.....	..
Victor	.....	P	O-N-V	1/200--1/10	1500	110--220	.....	..
Wagner	M	E-F-P	O-D-S-N-V-X	1/125--1/20	1000--1500	115--230	1/20--1/3	86
Wesche	T	E-F	O-D-S-N	.....	.....	.....	.....	..
Westinghouse	G-M-T	E-F-P	O-D-S-W-N-V-X	1/300--1/30	1000--1500	115	1/20--1/3	11
Wincharger (Winco)	.....	P	.....	.....	.....	.....	.....	..

(*) The maximum and minimum values for horsepower, speed and voltage are not direct-related to each other. Rather, they show the range of motors manufactured under each heading.

(§) Manufa

(†) Voltag

(1) Compl
at end

Ranges of Horsepower, Speed and Voltage fo

ALTERNATING-CURRENT MOT

SINGLE-PHASE TYPES

SPLIT-PHASE			CAPACITOR TYPES			REPULSION TYPES			SYNCHRONOUS		
(hp)	(rpm)[5]	(volt)	(hp)	(rpm)[5]	(volt)	(hp)	(rpm)[5]	(volt)	(hp)	(rpm)	(volt)
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	1/2--7-1/2	1200--3600	115--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/12--1/3	1200--3600	115--230	1/30--1-1/2	1200--3600	115--440	1/6--7-1/2	1200--3600	115--44C	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.0005--.005	3600	115
1/150--1/6	1125--3450	115--230	1/150--1/6	1125--3450	115--230	.....	.....	.....	1/2000--1/8	1800	115--23
1/6--1/3	1200--3450	115--230	1/6--3/4	1150--3450	115--230	1/6--7-1/2	1150--3450	115--230	.....	.....	.....
1/20--1/2	900--3600	100--250	1/20--20	900--3600	100--250	1/2--20	900--3600	100--250	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/6--1/3	1200--1800	115--230	1/6--3/4	1800	115--230	1/2--5	1800	115--230	.....	.....	.....
.....	.....	.....	1/4--3/4	850--1725	115--230	1/2--3/4	1725	115--230	.....	.....	.....
.....	.....	.....	1/30--3	900--3600	115--550	1--5	900--3600	115--550	1/30--1/2	1800--3600	115--55
Up to 1/10	600--3600	110--440	1/1000--1/6	600--3600	110--220	.....	.....	.....	1/1000--1/12	600--3600	110--22
1/500--1/15	1700--3400	115	1/500--1/10	1700--3400	115--230	.....	.....	.....	1/500--1/15	1800--3600	115
1/6--1/3	1800--3600	Up to 220	1/6--3	1800--3600	Up to 220	.....	.....	.....	1/6--2	1800--3600	Up to 2
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/20--1/3	1140--3450	115	1/8--3	1140--3450	115--230	1-1/2	1750	115--230	.....	.....	.....
.....	.....	.....	1/2--2	1200--3600	110--220	3/4--5	1200--3600	110--600	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/20--1/3	860--3450	115--230	1/6--5	1140--3450	115--230	2--10	900--3600	115--230	1/20--1	860--1725	115--230
.....	.....	.....	1/1000-1/500	3200	24	.....	.....	.....	.....	.....	.....
.....	.....	.....	1/100	3100	24	.....	.....	.....	.....	.....	.....
1/12--3/4	860--3450	115--230	1/5000--3/4	860--3450	115--230	.....	.....	.....	1/5000--1/3	900--3600	115--230
1/4--1/3	1140--3450	115	1/4--3	1140--3450	115--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	1/6--5	600--3600	110--220	.....	.....	.....	.....	.....	.....
1/8--1/3	1750--3400	115--230	1/6--1/2	1150--3450	115--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	1/125--1	1140--1725	115--230	.....	.....	.....	.....	.....	.....
1/20--1/8	1125--3450	115--230	1/150--1/8	1125--3450	115--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	1/20--1/4	5400--23000	115 †	.....	.....	.....	1/20	1800	85--115
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/20--1/3	860--3450	115--230	1/6--3/4	860--3450	115--230	1/4--5	1140--3450	115--230	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/20--1/3	860--3450	115--440	1/8--5	860--3450	115--440	1/3--7-1/2	860--3450	115--230	1/20--3/4	860--3450	115--440
1/30--1/4	1125--3600	110--230	1/30--1/6	1125--3600	110--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	1/10--1	850--3450	115--440	1/10--5	850--3450	115--440	.....	.....	.....
1/50--1/4	1200--3600	115--230	1/30--3/4	1200--3600	115--230	.....	.....	.....	1/30--1/10	1800--3600	115--230
Up to 1/10	1140--3450	115--230	Up to 1/12	1140--11000	115--230 †	.....	.....	.....	Up to 1/20	1200--3600	115
.....	.....	.....	1/4--1-1/2	1200--3600	115--230	1/6--5	900--3600	115--230	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	1--5	1800--3600	115--230	1--5	1800--3600	115--230	.....	.....	.....
.....	.....	.....	1/4--1/3	1725--3450	115--230	.....	.....	.....	1/20--1/8	1800	115--230
1/20--1/3	900--3600	115--230	1/250--7-1/2	900--3600	115--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/6--1/3	1140--1725	110--220	1/4--5	1200--3600	110--220	.....	.....	.....	.....	.....	.....
1/2--5	720--3600	55--550	1/2--5	720--3600	55--550	1/2--5	720--3600	55--550	.....	.....	.....
.....	.....	.....	1/2--3	600--3600	115--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	1-1/2--5	1800--3600	115--230	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	1/2--1	1800--3600	110--220	1/2--5	1800--3600	110--220	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/20--1/3	860--3450	115--230	1/6--3	860--3450	115--230	1/6--15	860--3450	115--230	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1/20--1/3	1140--3450	115--230	1/6--7-1/2	1140--3450	115--230	.....	.....	.....	1/250--1/3	900--3600	115--230
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

(§) Manufactures principally gearmotors.

(†) Voltage range includes high-cycle frequencies.

(1) Complete company names and addresses are listed at end of this article.

(2) Built-in features classified as:
B = Brakes or Clutches
G = Gearmotor
M = Multispeed motor
T = Thermal protection, overload.

r Typical Commercially Available Motors*

TORS										AC-DC MOTORS		
	POLYPHASE TYPES											
	SQUIRREL-CAGE			WOUND-ROTOR			SYNCHRONOUS			UNIVERSAL		
t)	(hp)	(rpm)[5]	(volt)	(hp)	(rpm)[5]	(volt)	(hp)	(rpm)	(volt)	(hp)	(rpm)	(volt)
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/4--600	450--3600	110--2300	1/2--600	450--3600	110--2300	.....	.....	.....	.....	.....	.....
.	1 and up	225--3600	110--2300	5 and up	225--1800	110--2300	40 and up	80--1800	220--2300	.....	.....	.....
.	1/3--20	900--1200	115--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
230	1/50--1/4	1725--3450	220--440	.....	.....	.....	1/150--1/8	1800	115--230	1/100--1/3	5000--10000	115--230
.	1/6--50	900--3600	220--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/6--400	450--3600	100--4000	1-400	450-1800	100--4000	15--400	900--1800	100--4000	.....	.....	.....
.	1/4--200	450--3600	208--2300	3/4--200	450--3600	208--2300	.....	.....	.....	.....	.....	.....
.	1/4-100	600--3600	220--440	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/4--25	850--3450	115--550	.....	.....	.....	.....	.....	.....	1/100--1/3	5000--18000	32--250
550	1--5	900--3600	115--550	.....	.....	.....	1/30--1/2	1800--3600	115--550	.....	.....	.....
220	1/750--1/6	600--3600	110--220	.....	.....	.....	1/750--1/12	600--3600	110--440	Up to 1/6	3000--14000	110--220
	1/500--1/15	1700--3400	115	.....	.....	.....	1/500--1/15	1800--3600	115	1/200--1/4	5000--15000	6--230
220	1/6--30	Up to 3600	Up to 550	1/6--30	Up to 3600	Up to 550	1/6--30	Up to 3600	Up to 550	.....	.....	.....
.	1--250	Up to 3600	110--2300	3--100	Up to 1800	220--2300	.....	.....	.....	.....	.....	.....
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/2--1500	300--3600	110--2300	3/4--1000	300--1800	110--2300	50--3500	514--1800	220--2300	.....	.....	.....
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/4-50	400--25000	Up to 600 ÷	.....	.....	.....	.....	.....	.....	.....	.....	.....
230	1/6 and up	450--3470	110--2300	1 and up	900--1800	208--550	1/6 and up	80--3450	208--2300	1/50--1/3	5000--10000	115--230
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	1/50--1/20	5000--7500	115--230
230	1/2500--1	860--3450	115--230	.....	.....	.....	1/20--3/4	1200--1800	115--230	1/25--1/8	1800--2100	115--230
.	1/4--5	1140--3450	208--440	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/6--200	600--3600	110--2300	1--150	600--1800	110--2300	.....	.....	.....	.....	.....	.....
.	1/6--3/4	1750	220--440	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/20--7-1/2	1140--1725	220--440	.....	.....	.....	.....	.....	.....	1/75--1/8	5000	115
.	1/20--1/4	1125--3450	115--440	.....	.....	.....	.....	.....	.....	1/500--2	3600--20000	115--250
15	1/20--2	7400-23000	200 ÷	.....	.....	.....	.....	.....	.....	1/50--1/8	4000--10000	120
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/30--5	860--3450	220--440	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/3--150	600--3600	110--600	.....	.....	.....	.....	.....	.....	.....	.....	.....
440	1/20--5000	450--3600	110--6000	1/2--5000	450--3600	110--6000	20--5000	100--1800	208--6000	.....	.....	.....
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/10--350	580---3450	115--2300	1/2--250	560--3450	115--2300	10--250	900--1800	220--2300	.....	.....	.....
230	1/8--5	850--3600	110--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Up to 1/8	1140--12000	220 ÷	.....	.....	.....	.....	.....	.....	1/1500--1/4	5000--25000	115--230
.	1/4--15	900--3600	208--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/100--25	4500--11500	110--220 ÷	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	1/200--1/10	Up to 20000	6--250
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	1/15--1/10	4000--10000	115--230
.	1/4--300	420--3500	208--2300	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1--150	900--3600	208--550	1--150	900--3600	208--550	1--5	900--3600	208--550	.....	.....	.....
230	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/8--125	900--3600	110--550	.....	.....	.....	.....	.....	.....	1/20--1/2	5000--10000	115--230
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	1/200	16000--25000	110--220
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	1/300--1/4	4000--10000	110--230
.	1/4--100	1200--3600	110--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/4--600	450--3600	55--2400	1/4--600	720--1800	110--2400	.....	.....	.....	.....	.....	.....
.	1/2--50	600--3600	110--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/4--250	900--3600	208--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/2-75	600--3600	220--550	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.	1/6--400	430--3500	110--2300	1--250	430--1750	110--2300	.....	.....	.....	.....	.....	.....
.	1--50	300--3600	110--600	1--50	300--3600	100--600	.....	.....	.....	.....	.....	.....
230	1/6 and up	450--3600	208 and up	1/2 and up	560--1775	208 and up	1/20 and up	514--1800	208 and up	1/150--2-1/2	1500--15000	115--230
.	.....	.....	.....	.....	.....	.....	.....	.....	.....	1/100--1/10	1500--25000	6--115

(3) Types of mounting classified as:
E = End, Flange or Face
F = Foot or Bracket
P = Parts or Shell type (motor stator and shaftless rotor).

(4) Types of enclosures classified as:
O = Open (non- semi- and protected, and skeleton)
D = Dripproof
S = Splashproof
W = Waterproof
N = Nonventilated, totally-enclosed
V = Ventilated, fan-cooled totally-enclosed
X = Explosionproof, totally-enclosed.

C RS		DIRECT-CURRENT MOTORS									MANUFACTURER OF MOTOR TYPES[1]
SAL		SHUNT			SERIES			COMPOUND			
)	(volt)	(hp)	(rpm)	(volt)	(hp)	(rpm)	(volt)	(hp)	(rpm)	(volt)	
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Alliance
	.....	1/2--200	250--3400	115--550	1/2--100	250--3400	115--550	1/2--200	250--3400	115--550	Allis, Louis
	.....	1 and up	Up to 3600	115--600	1 and up	Up to 3600	115--600	1 and up	Up to 3600	115--600	Allis-Chalmers
	.....	1/4--3	Up to 3600	32--230	1/4--3	Up to 3600	32--230	1/4--3	Up to 3600	32--230	Baldor Electric
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Barber-Colman
000	115--230	1/50--1/6	1125--3450	115--230	1/100--1/3	5000--10000	115--230	.....	.....	.....	Bodine Electric
	.....	1/6--5	1140--3450	32--230	.....	.....	.....	1/6--5	1140--3450	32--230	Brown-Brockmeyer
	.....	1/20--200	300--3600	6--600	1/20--200	300--3600	6--600	1/20--200	300--3600	6-600	Century
	.....	1/2--200	150--3500	115--230	1/2--200	150--3500	115--230	1/2--200	150--3500	115--230	Crocker-Wheeler
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Delco
000	32--250	.....	.....	.....	.....	.....	.....	.....	.....	.....	Diehl
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Doerr
000	110--220	1/200--1/25	Up to 7000	110--220	1/1000--1/5	Up to 14000	110--220	.....	.....	.....	Electric Indicator
000	6--230	1/200--1/15	2500--10000	6--115	1/200--1/4	5000--15000	6--115	.....	.....	.....	Electric Motor
	.....	1/6--15	Up to 4000	Up to 600	1/6--15	Up to 4000	Up to 600	1/6--15	Up to 4000	Up to 600	Electric Specialty
	.....	1--150	Up to 1800	115--550	1--150	Up to 1800	115--550	1--150	Up to 1800	115--550	Electro Dynamic
	.....	.....	.....	.....	.....	.....	.....	3/4--5	1150--1750	115--230	Emerson
	.....	3/4--500	600--3600	115--230	3/4--500	600--3600	115--230	3/4--500	600--3600	115--230	Fairbanks Morse
	.....	1/500--1/250	3500--20000	6--48	1/500--1/250	3500--20000	6--48	.....	.....	.....	Fasco
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Forbes & Myers
000	115--230	1/2 and up	575--3500	115--230	1/20 and up	575--5000	115--600	1/20 and up	575--3500	115--230	General Electric
	.....	1/8	2000--3000	6	1/100--1/3	2500--7500	6--24	.....	.....	.....	General Industries
00	115--230	1/50--1/25	5000--7500	115--230	1/100--1/25	5000--7500	115--230	.....	.....	.....	Heinze Electric
00	115--230	1/100--1-1/2	875--3450	20--230	1/50	1800	230	1/40--1-1/2	850--3450	20--250	Holtzer-Cabot
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Hoover
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Howell
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Jack & Heintz
	115	1/20--7-1/2	1140--1725		1/20--7-1/2	1140--1725	.....	1/20--7 1/2	1140--1725	.....	Janette (§)
000	115--250	1/150--1/2	1500--15000	6--250	1/150--1/2	1500--15000	6--250	1/6--1/2	1150--3450	6--250	Lamb Electric
000	120	1/100--1/8	2000--15000	12--30	1/100--2	6000--20000	12--30	1/100--1	2000--15000	12--30	Lear
	.....	1/4--5	1500--8000	6--32	1/100--30	1000--10000	6--64	1/4--5	1500--8000	6--32	Leece-Neville
	.....	1/4--1	860--3450	32--230	1/4--1	860--3450	32--230	1/4--3	860--3450	32--230	Leland
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Lima Electric
	.....	1/20--5000	100--6000	6--600	1/20--5000	100--6000	6--600	1/20--5000	100--6000	6--600	Marathon
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Marco
	.....	1/10--15	575--3500	12--600	1/10--15	575--3500	12--600	1/10--15	575--3500	12--600	Master Electric
	.....	1/30--1/8	850--3600	32--230	1/30--1/4	1800--10000	32--230	1/4--3/4	850--3600	32--230	Ohio Electric
000	115--230	Up to 1/4	2000--12000	6--220	Up to 1/4	4000--20000	6--220	Up to 1/4	2000--15000	6--220	Oster
	.....	1/3--3	Up to 1750	32--230	.....	.....	.....	1/3--3	Up to 1750	32--230	Peerless
	.....	1/100--10	1800--15000	6--120	1/100--10	1800--15000	6--120	1/100--10	1800--15000	6--120	Pesco
000	6--250	1/200--1/30	Up to 3500	6--125	1/200--1/10	Up to 20000	6--250	.....	.....	.....	Rae Motor
000	115--230	1/1000--1/10	1500--10000	6--115	1/1000--1/10	1500--10000	6--115	.....	.....	.....	Redmond
	.....	1/2--200	100--3500	115--230	1/2--200	100--3500	115--230	1/2--200	100--3500	115--230	Reliance
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Reuland
	.....	1/20--1/4	1725--3450	32--230	.....	.....	.....	1/3	1725--3450	115--230	Reynolds (Reco)
000	115--230	1--7-1/2	900--3600	110--550	1--7-1/2	900--3600	110--550	1--7-1/2	900--3600	110--550	Robbins & Myers
6000	110--220	.....	.....	.....	1/8	8000	110--220	.....	.....	.....	Scruggs
000	110--230	1/500--1/10	1100--2400	110--230	1/300--1/4	3000-6000	6--230	.....	.....	.....	Signal Electric
	.....	.....	.....	.....	.....	.....	.....	1/4--5	1150--1750	32--500	Smith
	.....	1/4--200	250--3450	32--600	1/2--25	250--3450	24--230	1/4--200	250--3450	32--600	Star-Kimble
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Sterling
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	U.S. Electric
	.....	1/100--1/10	1600--15000	6--115	1/100--1/10	1600--15000	6--230	.....	.....	.....	Universal
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Valley
	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Victor
	.....	.....	.....	.....	1/125--1/20	1000--1500	115--230	1/20--3	860--3450	115--230	Wagner
	.....	1--50	300--3600	32--600	1--50	300--3600	32--600	1--50	300--3600	32--600	Wesche
000	115--230	1/20 and up	100--3450	115 and up	1/20 and up	750--1600	115 and up	1/20 and up	100--3450	115 and up	Westinghouse
000	6--115	.....	.....	.....	.....	.....	.....	.....	.....	.....	Wincharger (Winco)

skeleton)

(5) Speeds are listed either as synchronous or full-load. If synchronous speeds (3600, 1800, 1200, 900, etc.) are listed, motor slip (usually less than 5 per cent) determines full-load speed.

Table 16—Full-Load Speeds for Fractional-Horsepower Induction Motors*

(for 60-cycle current)

Motor Rating (hp)	No. of Poles	Synchronous (rpm)	Shaded-Pole (rpm)	Split-Capacitor (rpm)	All Others (rpm)
0.001	2	3600	3000	3000	3450
to	4	1800	1550	1550	1725
0.035	6	1200	1050	1050	1140
	8	900	800	800	....
1/20	2	3600	3000	3250	3450
to	4	1800	1550	1625	1725
1/8	6	1200	1050	1075	1140
	8	900	800	825	850
1/6	2	3600	....	3250	3450
to	4	1800	....	1625	1725
1/3	6	1200	....	1075	1140
	8	900	....	825	850
1/2	2	3600	....	3250	3450
to	4	1800	....	1625	1725
1†	6	1200	....	1075	1140

* From NEMA Standards.
† Applies only fractional-horsepower ratings, i.e., for ¾-hp, only 2 and 4-pole and, for 1-horsepower, only 2-pole.

Table 17—Breakdown Torque Values for Single-phase Induction Motors*

(60-cycle current)

Motor Rating	Min. Breakdown Torque†		
	2-Pole§	4-Pole§	6 Pole§
(hp/1000)	(oz-in.)	(oz-in.)	(oz-in.)
1	0.35	0.7	1.1
1.5	0.55	1.1	1.65
2	0.7	1.45	2.2
3	1.1	2.2	3.3
5	1.8	3.6	5.4
7.5	2.7	5.4	8.1
10	3.6	7.2	11
15	5.5	11	17
25	9.5	19	29
35	15	30	46
(hp)	(oz-ft)	(oz-ft)	(oz-ft)
1/20	2.0	4.0	6.0
1/12	3.7	7.1	10.4
1/8	6.0	11.5	16.5
1/6	8.7	16.5	24.1
1/4	11.5	21.5	31.5
1/3	16.5	31.5	44.0
1/2	21.5	40.5	58.0
3/4	31.5	58.0	**
1	44.0	**	**
(hp)	(lb-ft)	(lb-ft)	(lb-ft)
3/4	**	**	5.16
1	**	5.16	6.9
1-1/2	3.6	6.8	9.2
2	4.6	10.1	13.8
3	6.0	13.0	18.0
5	8.6	19.0	25.8
7-1/2	13.5	30.0	40.5
10	20.0	45.0	...

* Based on NEMA Standards.
** Ratings tabulated in oz-ft or lb-ft, either above or below in same column.
† Torque values may range between minimum and value for next larger motor.
§ 2-pole, 4-pole and 6-pole motors have synchronous speeds of 3600, 1800 and 1200 rpm respectively.

Table 18—Starting Torque and Current at Rated Voltage

(60-cycle)

Motor Rating (hp)	Torque†			Current§ All Motors	
	2-Pole† (oz-ft)	4-Pole† (oz-ft)	6-Pole† (oz-ft)	115v (amp)	230v (amp)
1/8	..	24	32	20	10
1/6	15	33	43	20	10
1/4	21	46	59	23	11½
1/3	26	57	73	31	15½
1/2	37	85	100	45	22½
3/4	50	f19	...	61	30½
1	61	...	...	..	..

* Based on minimum locked rotor torques from NEMA Standards.
† Motors with 2, 4 or 6-poles have 3600, 1800 or 1200 rpm synchronous speeds, respectively.
§ Maximum values of current based on locked-rotor conditions.

TYPICAL RATINGS OF MOTORS BUILT BY VARIOUS MANUFACTURERS

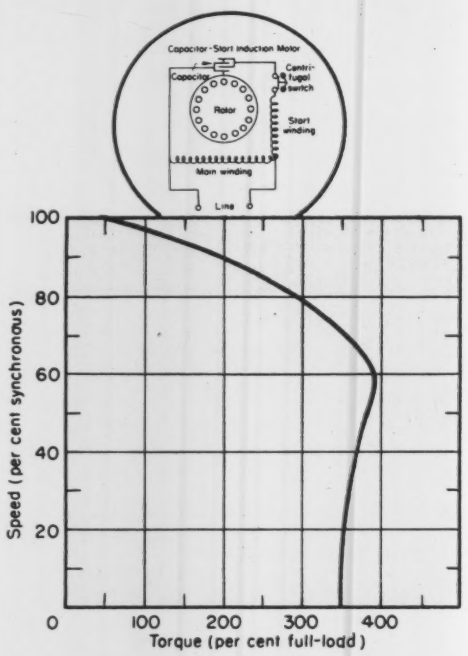


Fig. 51—Typical speed-torque curve for a capacitor-start induction-run fractional-horsepower motor having 350 per cent full-load torque for starting heavy loads

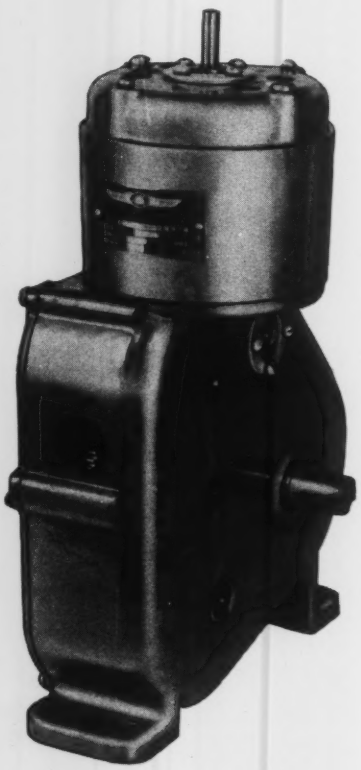


Fig. 52—Reversible capacitor-induction motor operating submersed in oil. A high-torque motor, it develops 1/45-horsepower and can be stalled for extended periods without harm

—Courtesy, Lamb Electric Co.

generated is also constant. Power factor, although usually unimportant is relatively low, being about 20 per cent at no load and increasing to 60 per cent at full load. In general, split-phase motors should not be employed where the starting torque exceeds 150 per cent of the full-load torque.

This motor, in the past, has been the most used type of the single-phase motors for fractional horsepower service. Its advantages are relatively low cost and good running characteristics if starting is not too frequent. Limitations involve the requirement of a starting winding with a starting switch for switching to the running winding after the motor has accelerated. This switch is usually a centrifugal device, although current relays are employed in some designs. Current relays switch to the running winding when the rotational speed of the motor has developed sufficient back electromotive force to reduce the current, operating the switch. Another limitation of this motor is its relatively high starting current, the inrush peak being as much as twice the full-load current.

Another form of this motor retains the starting winding in the circuit at all times, obviating a centrifugal switch or relay. Known as the permanent split-phase motor, it is useful for driving fan, blower and other drives where starting loads are light.

Speed adjustments are employed on permanent split-phase motors by varying the primary voltage with an autotransformer. Speed regulation however, is very poor, the method being most useful for constant loads such as for fans. Speed-torque curves are similar to those (*Fig.* 54) discussed later for capacitor motors.

Split-phase motors, depending on starting windings to give direction of rotation, cannot be reversed while running. This motor is classified as a reversible-from-rest motor and cannot be reversed until its speed has dropped sufficiently for the centrifugal switch to reconnect the starting winding. This may occur at approximately half-speed, at which time the reversing switch would brake and reverse the motor. The motor is not designed for reversing at reduced speed and over-heating or burnout might result from frequent operation. Furthermore, operation might be erratic inasmuch as, even though the reversing switch is operated, the motor would continue running in its original direction if the starting winding is not reconnected by the centrifugal switch. Illustrated in *Fig.* 49 are speed torque curves for a 1/10-horsepower, 1725-rpm split-phase motor.

These motors have been employed traditionally for driving domestic washing machines and for similar general-purpose duty such as small tools and office appliances requiring an economical motor and constant speed.

In *Fig.* 50 is a 1/15-horsepower split-phase motor driving a Beckman and Whitley camera. This drive unit is mounted on rubber shear members in the lower part of the camera housing. The cone and friction-ring planetary speed reducer to the right of the motor is continuously adjustable from 0 to 3000 rpm. The drive unit is closely quartered in the small housing of the camera. A totally-enclosed motor is employed

because, in operation of the camera, it is important that no lubrication escapes from the motor into the camera mechanism.

Capacitor Motors: With the development of better dielectrics for capacitors, making them more compact and more dependable, the capacitor-start induction-run motor has become the most popular general-purpose motor for single-phase drives. It bridges the cost and performance gap between the split-phase and repulsion-start induction-run motor. In electrical design it is actually a split-phase motor with a capacitor inserted in series with the starting winding. This markedly improves starting or breakaway torque, which is about 200-350 per cent of full-load torque.

This motor can be so designed as to have practically the same desirable characteristics of low starting current with high starting torque as the repulsion-start motor. Its cost over the conventional split-phase motor is increased only by the cost of the capacitor. As capacitors become less expensive, the motor becomes more competitive with the split-phase unit. Little disadvantage is suffered by the capacitor motor due to the capacitor mounting which may be on the motor top or side, within the base, around the frame, or in a remote location.

It is interesting to note that a split-phase motor may be operated as a capacitor-start motor by inserting a capacitor in series with the starting winding. The proper capacitance would improve the motor characteristics by reducing the starting current and increasing the starting torque. Likewise, a capacitor-start motor may have the capacitor disconnected to operate as a split-phase motor.

There are basic types and many design variations of capacitor motors, requiring that a motor be identified specifically, such as capacitor-start induction-run. Other types are permanent-split or single-value and two-value. These may be two-speed or multispeed. The single-value and two-value permanent types all retain a capacitor permanently in series with the running windings. Some do not require a switching device, effecting two-phase motor operation from a single-phase power supply and running quietly without vibration.

A permanent-split capacitor motor, often called a single-value capacitor motor, employs the same value of capacitance for both starting and running conditions. In this design, starting torque usually is sacrificed, being only 1 to 1½ times full-load torque.

An unusual design of an electrically reversible split-capacitor motor, however, has high torques comparable to other capacitor motors. This design will be discussed in the section on reversing. A two-value capacitor motor utilizes different values of capacitance for starting and running to improve characteristics, having practically the same speed-torque relationship as capacitor-start induction-run motors. This, however, complicates the electrical circuit somewhat. Two-speed and multispeed capacitor motors have various methods of interconnections, sometimes involving autotransformers. In some motors, speed variations are obtained by increasing the slip. Such motors, however, would more properly be classified as adjustable variable-speed motors instead of multi-speed.

A typical speed-torque curve for a capacitor-start induction-run motor having a fractional-horsepower rating is shown in *Fig.* 51. This motor has a starting torque (locked-rotor) of 350 per cent full-load torque and a breakdown torque approaching 400 per cent. Two-value capacitor motors have torque characteristics practically identical to those shown in *Fig.* 51 and are noteworthy in this respect because electrical features have been substituted for a mechanical, i.e. a capacitor is substituted for a centrifugal switch. This motor shows promise of eventually supplanting the capacitor-start types. Present limitations involve the size and cost of the capacitors required. The capacitors, being continually in the running circuit, are relatively large and are oil type at present.

How one problem of unusual service requirements was solved through the use of a reversible capacitor motor is illustrated in *Fig.* 52. A 4-pole, 1/45-horsepower motor operating on 115 volts at 60-cycles drives a tap changer through a gear reducer. This motor is required to operate fully submerged in oil, to reverse under power and withstand locked rotor conditions continuously. The rotor is open to the oil as is also the gearing, providing lubrication. Smooth contours on the rotor reduce turbulence and drag. Speed of the output shaft is 0.88-rpm through reduction gearing having a ratio of 1785:1 obtained through one worm and four stages of spur gears. The gear case is die-cast zinc while the motor frame is sand-cast aluminum. The entire motor is treated with phenolic varnish to resist oil immersion. The locked-rotor watts are selected so that the motor can dissipate generated heat continuously without damage.

Reversing: Capacitor-start induction run motors may be reversed from rest only, similar to split-phase motors. That involves reversing the leads for the starting winding. Inasmuch as the starting winding is in the circuit only when the centrifugal switch is closed, the motor must be stopped or must be running at a reduced speed sufficiently low to close the switch. Such a motor requires four leads, two for each winding, and a double-pole double-throw switch for reversing. Of course, reconnection of leads manually would reverse the motor if reversing is not a part of the duty cycle. Then, as with other single-phase, a single-pole single-throw switch is used for start-stop operation.

Conventional permanent split-capacitor motors are reversible electrically while running because the capacitor is in series with its winding while the motor is running. Four leads are required as in the capacitor-start motor and connections are made similarly, the only difference being in performance in that the split capacitor motor reverses while running. These connections are shown schematically in Fig. 53*a* and *b*, connected with a double-pole double-throw switch.

One of the most unusual of the capacitor motors is the split-capacitor motor having two identical windings with a capacitor connected between the two leads as indicated in *Fig.* 53*c*. It is noteworthy because of its simplicity, requiring only a single-pole double-

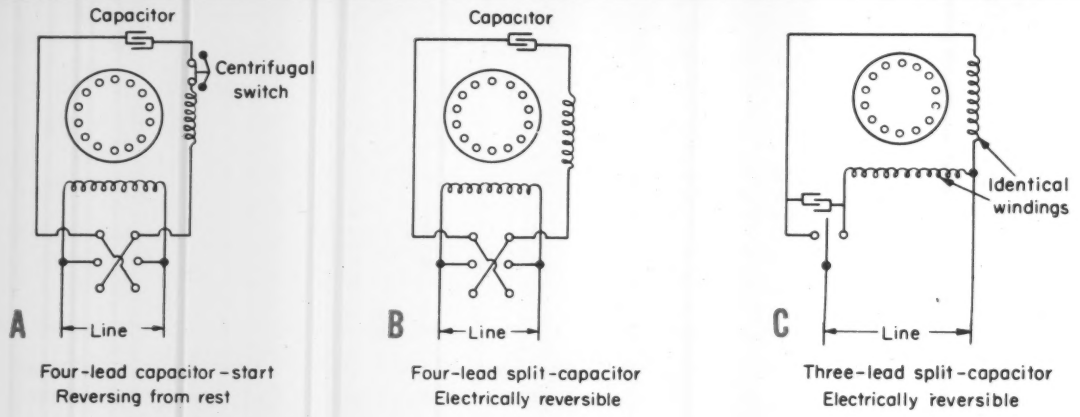


Fig. 53—Methods employed for reversing different capacitor motors. The capacitor-start motor at(a)is reversible from rest only. Those at(b)and(c)are electrically reversible while running

throw switch. When the switch is in one position the capacitor is in series with one winding. When the switch is in the other position, the capacitor is in series with the second winding, reversing the motor.

This motor differs from all the others in several respects. Unlike the other permanent split-capacitor (one-value) motors it develops high torque like the capacitor-start. Unlike the capacitor-start motor it is electrically reversible like the single and two-value motors. Unlike all the others its reversing connections are simple. Only three leads are required for connection which allow the use of a single-pole double-throw switch as shown in the sketch instead of a double-pole double-throw control required by the others. Because of its simple and instantaneous reversing characteristics, not found in other single-phase motors, it is utilized extensively for small hoists, door operators, etc.

Multispeeds: Two or more speeds are obtained from split-capacitor motors either by voltage control of the field windings with an autotransformer or by tapped field windings. Either method increases the slip of the motor and decreases motor output. However, for fan loads the methods have proved extremely satisfactory and are widely employed for ventilating and air conditioning equipment.

These variable-speed drives are not used for general-purpose duty, being restricted usually to shaft mounted fans and blowers. The torque characteristics are satisfactory for these uses. As a matter of interest regarding matching permanent-capacitor motors to the driven load, it is necessary that the motor be fully loaded at top speed if it is to operate, say, at 860-1140 rpm. Otherwise, a small change in speed will be obtained on the low-speed setting, resulting in speeds of 1000-1140 rpm.

Two-speed operation is obtained usually by three-position toggle switches for high-low-off operation, providing series-parallel or tapped connections of the windings to give a low speed approximately 65 per cent of high speed. Multispeed operation is obtained from a tapped transformer which varies the motor from top speed to approximately 50 per cent. Whether it is two-speed or multispeed depends upon the control utilized.

For obtaining speed adjustments of capacitor motors by primary voltage control, an autotransformer is used to vary the voltage input as shown in *Fig.* 54. The torque-speed curves show that speed regulation for varying loads is very poor. In view of this fact, such a circuit is most applicable to constant loads. The practical speed ranges for this type of system are approximately two or three to one, with a 50 to 35 per cent speed reduction by voltage control. Although permanent-capacitor motor characteristics are shown in *Fig.* 54, these curves could equally well represent a permanent split-phase or repulsion type of motor.

REPULSION TYPES: The repulsion-start induction motor has been the traditional workhorse in the single-phase family. Where low starting currents and high starting torques are desired no other motor matches its performance except perhaps the capacitor-start and two-value capacitor types.

Like the capacitor types of motors, repulsion types must be designated carefully. All have wound rotors, commutators and brushes and are defined as follows: (1) *Repulsion* motor has the brushes on the commutator short-circuited and so placed that the magnetic axis of the resulting rotor winding is inclined to the magnetic axis of the stator. This motor has a varying speed characteristic. (2) *Repulsion-start induction motor* has windings similar to the repulsion motor but after starting the rotor windings are all short circuited to form a squirrel-cage winding to operate with the constant-speed characteristics of an induction motor. (3) *Repulsion-induction motor* operates with both a repulsion winding and a squirrel-cage winding on the rotor. This motor may have either constant-speed or varying speed characteristics, depending on its design.

In most recent designs of the repulsion types of

motors, starting torques are not developed by auxiliary field windings as in other single-phase motors. Instead the magnetic field induces current flow in those rotor windings which are short circuited by the brushes. The motor torque is the resultant force, tangent to the rotor, produced by the mmf of the field and the induced mmf in the rotor.

Although the characteristics of a repulsion-start induction motor are highly useful, it is relatively more costly than other types because of the added features of brushes, commutator, and brush-shifting device. In addition the repulsion-start motor requires a centrifugal switch to short-circuit the windings. Also, to reduce maintenance some types utilize a brush-lifting mechanism.

Characteristics of a typical repulsion-start induction motor are shown in *Fig.* 55. Operation as a repulsion motor and switched operation as an induction motor are both shown. Typical starting torques of these motors are about 400 per cent of full-load torque and maximum running torques are about 275 per cent.

Straight repulsion motors have characteristics like series motors in that the speed varies according to the load. Some designs have external brush shifting devices for speed control. For constant-load applications like printing presses, textile machines having constant-torque requirements, etc., this arrangement provides a simple and effective control, obviating external auxiliaries such as resistors.

Repulsion-induction motors, having squirrel-cage windings buried beneath the repulsion winding on the rotor, operate with the combined effects of both windings. Its characteristics depend on the method in which these windings are combined and their relative electrical strength. Any combinations of speed-torque relations, varying between the repulsion and induction motors, are possible.

Reversing: These motors are reversible either by reconnecting the windings or by shifting the brushes. Repulsion start induction motors having a centrifugal device are reversible at standstill only. The other two types are reversible electrically and plugging reversals are possible, i.e., current reversed while motor is running.

Multispeeds: Speed adjustment is obtainable for repulsion-run motors by brush shifting, as mentioned previously, and by primary voltage control through an autotransformer. Speed-torque curves for the latter method are similar to these shown for a permanent split-capacitor motor in *Fig.* 54.

SYNCHRONOUS MOTORS: Differing from all other motors, the synchronous motor is truly constant speed. It cannot run with any slip. If it starts to slip, due to overload, it pulls out of synchronism and stalls. So-called self-starting synchronous motors are designed so that the pull-out torque is higher than the starting torque to preclude the possibility of operating below synchronous speeds. Speeds are determined by the number of pairs of poles and are always a whole number ratio of the frequency. For instance, on 60-cycle operation, the actual running speeds must be in the series of 3600, 1800, 1200, 900, 720 rpm, etc. For 50 cycles, the speeds are 5/6 and for 25 cycles the speeds are 5/12 the corresponding speed of 60-cycle operation.

No motor, either single-phase or polyphase, can start as a synchronous motor. Accelerating from zero speed would require slip until synchronism is reached. Therefore, separate starting means must be employed. In the miniature and fractional-horsepower sizes, self-starting designs are employed. These automatically switch to synchronous operation due to the electrical characteristics of the motor.

Self-starting synchronous motors may start as any of the well-known motor types, i.e., shaded pole, split-phase, capacitor, repulsion, etc. Rotor construction, however, has definite mechanical poles obtained by slotting-out sections in the rotor. This, of course interferes with the electrical starting characteristics, reducing the starting torque available. This is further complicated by inability to design high torque in the starting circuit because that would require high slip. A high-slip design could not accelerate the rotor to a sufficiently high speed to pull it into synchronism. As a result, both requirements militate against developing high starting torque.

Starting torques for synchronous motors depend upon the electrical type of design used to accelerate the rotor. According to type these starting charac-

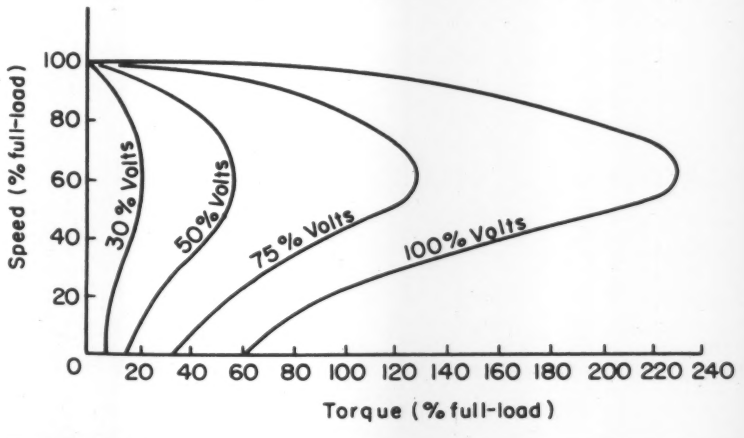
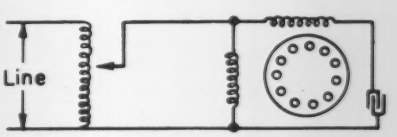


Fig. 54 — Speed-adjustment curves for a permanent split-capacitor motor obtained by primary voltage control through an autotransformer. These curves would also be typical for permanent split-phase and repulsion-run motors

—Data, courtesy Westinghouse Electric Corp.



teristics are, for four-pole motors, based on locked-rotor torque percentage of full-load torque:

Type	Locked Rotor Torque (% full load)
Permanent-split capacitor	85
Split-phase induction	85-175
Capacitor-start induction	175-250
Polyphase squirrel-cage	175-250

Pull-out torques, being related to the characteristics of the synchronous operation are between 175 and 220 per cent of full-load torque for four-pole motors. These torques apply to reluctance type synchronous operation, usually employed for nonexcited motors of the types tabulated for starting torques. Separately or self-excited motors, i.e., those in which dc current is supplied to the rotor windings have better characteristics. Such motors, however, are generally for larger horsepower ratings.

Typical characteristics for speed, horsepower and current plotted against torque are shown in *Fig.* 56. These curves are for a 1/75-horsepower, single-phase, 60-cycle motor. It is a split-phase start, reluctance-operating synchronous motor.

Synchronous operation of a motor employs one of the following methods to obtain its electrical characteristics:

1. Separately excited
2. Self-excited
3. Nonexcited
   a. Reluctance
   b. Hysteresis
   c. Permanent magnet
   d. Cog or Saga type.

The separately excited and self-excited motors are called true synchronous. They are built in sizes larger than ½-horsepower and utilize wound rotors. The windings require direct-current supplied through slip rings.

Reluctance types are the more usual of the nonexcited forms. Hysteresis types have solid metal rotors which are sometimes slotted or punched. These motors are made in sizes less than 1/20-horsepower. Typical are the cobalt-rotor (smooth rotor) and clock motors. The cobalt hysteresis motor, *Fig.* 57, differing from other synchronous motors has a heat-treated cobalt-cylinder rotor and is capable of random pole orientation. It will pull any practical inertia load into synchronism. It does not vibrate as much as the split-phase type of reluctance motors, but is more sensitive to voltage change and is relatively expensive. Capacitor and polyphase reluctance motors are also smoother in operation than the split-phase synchronous motor. Permanent-magnet types usually have Alnico inserts to provide salient poles. The cog type is an unusual slow-speed motor. It is not self-starting and is best known for its use in clocks and record-player turntables.

Synchronous motors are not employed for general-purpose duty. They are used only (except for power-factor correction) where accurate and constant speeds are paramount requirements. Applications include recording instruments, sound-recording equipment, timers, sound cameras and projectors. Illustrated in *Fig.* 58 is a synchronous motor driving a timer for register control in a color printing press. Requirements called for a small compact synchronous slow-speed motor capable of being reversed easily while in motion.

In *Fig.* 59 is a fan-cooled, skeleton-type, shaded-pole synchronous motor driving the recording chart of a magnetic oscillograph. The motor develops 0.004-

Fig. 55—Characteristic torque and current curves for a repulsion-start induction motor showing both phases of motor operation

—Courtesy, Wagner Electric Corp.

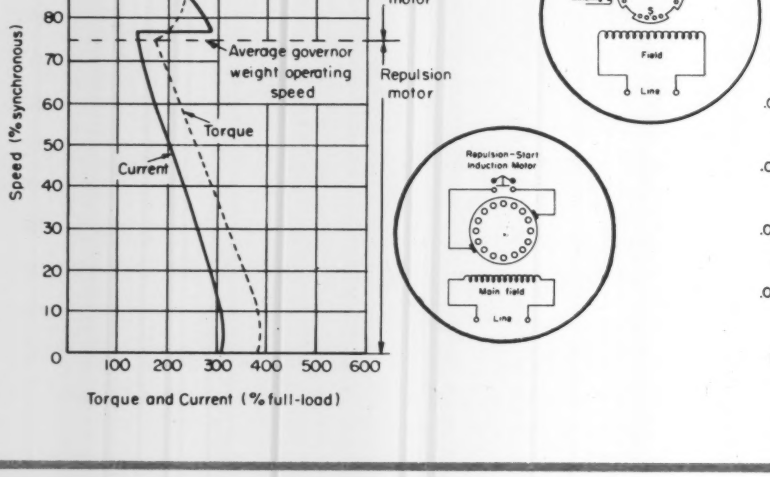
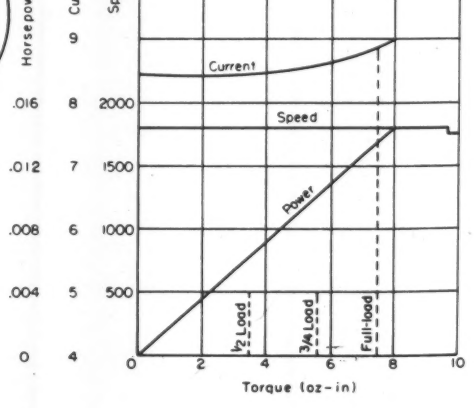


Fig. 56—Speed, horsepower and current plotted against torque for a typical 1/75-horsepower, 4-pole synchronous motor

—Courtesy, Bodine Electric Co.



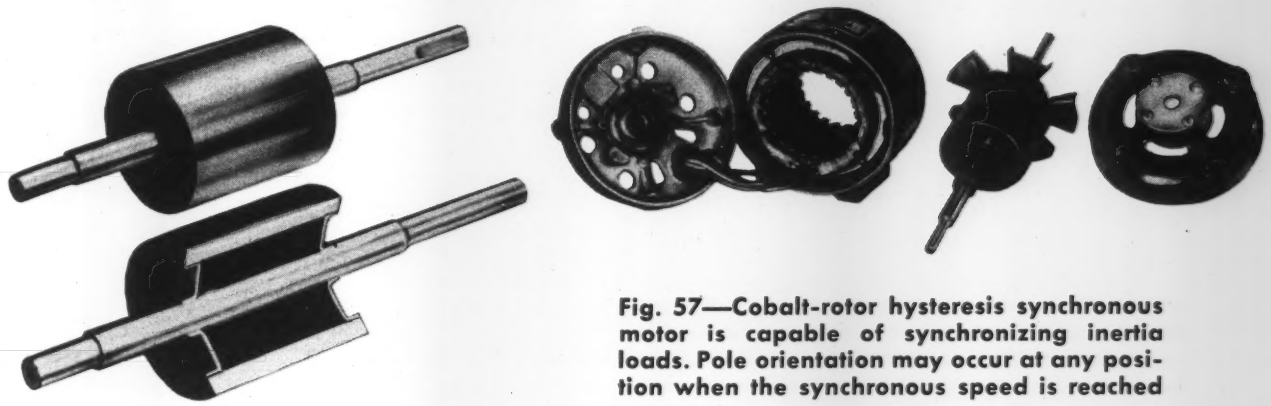


Fig. 57—Cobalt-rotor hysteresis synchronous motor is capable of synchronizing inertia loads. Pole orientation may occur at any position when the synchronous speed is reached

—Courtesy, Bodine Electric Co.

horsepower at absolute synchronous speed. Application required a compact inexpensive motor.

A system of parallel operation of many drive motors has recently been developed to utilize synchronous motors. Speed of these motors is controlled by varying the frequency delivered to them from an adjustable-speed motor-generator set. Each motor then, regardless of individual loads, operates at an exact speed with respect to the generated frequency of the generator. The system involves fewer components and has higher efficiency than a comparable dc drive. Speed regulation over the entire system is within 0.1 per cent over a 7:1 speed range.

Fig. 58—Synchronous motor driving a Hurleton timer employed for photoelectric color registration on rotogravure presses

—Courtesy, Bodine Electric Co.

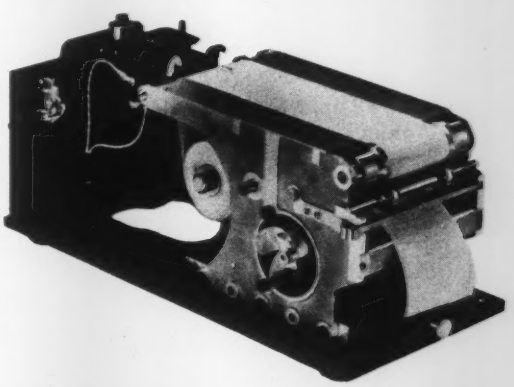


Fig. 59—Shaded-pole synchronous motor driving an oscillograph recording chart

—Courtesy, Barber-Colman Co.

UNIVERSAL MOTORS: Essentially a direct-current series motor, the universal motor has its electrical characteristics altered so that operation on either ac or dc current is as near alike as possible. Because it has the distinct advantages of operation on either power supply, of high starting torque and of compact design, the universal motor is popular for use in domestic appliances such as food mixers and sewing machines, office machines such as adding machines and tabulators, and small tools such as grinders and drills.

This motor has variable-speed characteristics tending to "run away" at increasing speed when no load is applied, the limiting speed being windage and friction loads to balance the torque at an equilibrium point. For this reason the motor is usually direct-connected to its load. On an adjustable speed application it is usually governed by a variable rheostat or an adjustable governor controlling electric contacts.

Having a wound rotor, a universal motor requires brushes and commutator, its chief disadvantage because of the maintenance attention involved. Where its variable-speed and high-speed characteristics are advantageous, no other motor is available.

When operating on direct-current the motor runs at slightly higher speed than when operating on alternating current, the reason being that the effective voltage is higher, no eddy currents being set up by the cycling voltage. When a closely governed speed is required for either power supply, a resistor is usually included in the circuit for connecting in series with the motor for dc operation.

Universal motors are basically high-speed motors. Because of this fact they are widely employed with gear reduction to provide a lightweight compact motor for portable tools. With the gear reduction, high starting and breakdown torques are developed which make them particularly desirable drives.

Capable of developing speeds as high as 25,000 rpm for 2-pole 60-cycle designs, the universal motor has a peak efficiency of about 60 per cent at rated

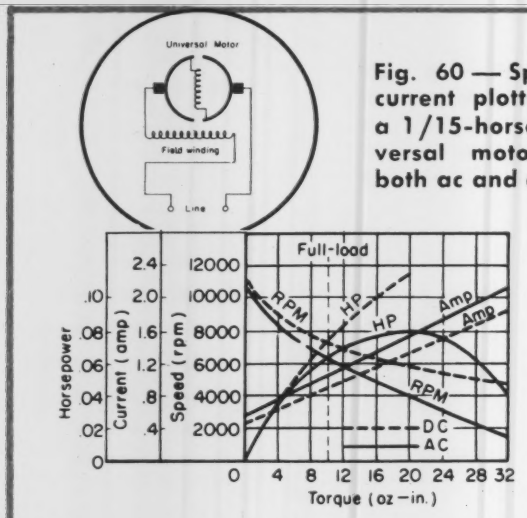
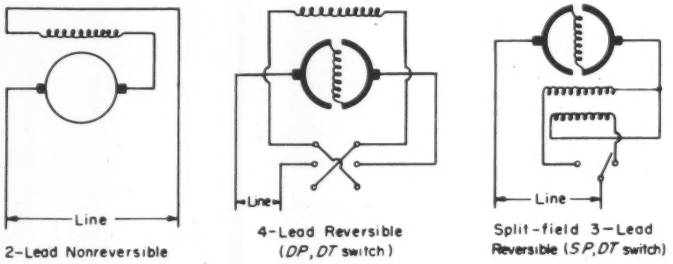


Fig. 60 — Speed, horsepower and current plotted against torque for a 1/15-horsepower, 6500 rpm universal motor. Characteristics for both ac and dc operation are shown

—Courtesy, Bodine Electric Co

Fig. 61—Connections for reversing universal motors, showing field-current reversal for both 3-lead and 4-lead motors



—Courtesy, Bodine Electric Co.

load. The torque does not have a characteristic breakdown like an induction motor but increases almost proportionally with decreased speed below full load until stalled torque is reached from 5 to 10 times rated torque. For starting duty this torque is available to break-away a high load. These motors are built only in small sizes, usually fractional-horsepower. Two horsepower is about the largest. Efficiency is relatively low and the motor is unsuitable for driving varying loads which require constant speeds. When properly applied, however, the universal motor is one of the most versatile of the single-phase type motors.

Typical speed, horsepower and current curves for a universal motor are shown in *Fig.* 60. Both ac and dc operation are plotted for this 1/15-horsepower, 6500-rpm motor, showing the higher operating characteristics for direct current. This feature is generally true for universal motors because of the steady value of the unidirectional flow of dc current. Although design minimizes this feature inasmuch as possible, resistors are employed in series with the windings on dc operation when the same speeds are desired from both types of current. This practice is used on dictating machines, etc.

Reversing: Universal motors are reversible either from rest or while running by reversing the current flow either in the rotor or field windings. On motors with two leads, however, it would be necessary to change the connections inside the motor. If reversing is specified the motor is supplied with either three or four leads. Connections for these motors are shown in *Fig.* 61. The four-lead motor is the simpler in construction but requires a double-throw double-pole switch if switching is desired. The three-lead motor requires only a single-pole double-throw switch but involves a double-field winding as shown.

Speed Control: When preset and definite speeds are desired, governor-controlled contacts are employed rather than voltage control through a rheostat because, with the latter, available torque would be reduced and speed would vary with the load. The normal universal type motor has a steep speed-torque curve. By means of a speed-sensitive or centrifugal-governor type of contact mounted on the motor itself, it is possible to limit the top speed of the motor.

Referring to *Fig.* 62 it can be seen that the speed can be "chopped off" to limit the maximum speed characteristic. In normal applications, the basic circuit makes use of a resistor and capacitor across the centrifugal-governor contacts. This combination is used to improve contact life of the governor mechanism. It can be seen that a fairly flat speed-torque curve can be obtained by means of this system. By changing the operating point of the governor contacts, it is possible to maintain any particular speed within the range of the motor. This type of system is usually applied on machines such as calculating machines, office equipment, electric typewriters, and any other device requiring fairly good speed-torque characteristics and an economical motor drive.

Shown in *Figs.* 63 and 64 are a governor-controlled motor and the electrical circuit for obtaining two governed speeds. Housing of the motor is cast aluminum and rubber pads are affixed to the mounting holes for quiet operation. As shown in *Fig.* 64, high-speed operation is obtained with switch S_2 closed, bypassing the low-speed governor contacts and its resistor. If low speed is desired the switch is opened and the low-speed governor contacts control the current supply to the motor as shown. Also, a reversing switch S_1 controls the direction of current flowing in the field circuit. In this way two definite speeds are obtainable in either direction in this instantly reversible motor.

On adjustable speed applications, one set of contacts is employed, centrifugal operation of the contacts being controlled by a manual governor setting. Typical of this type of control is that employed for household food mixers.

Indicative of the potentialities of the universal mo-

tor as a compact, lightweight drive for developing high torques is the billing machine drive illustrated in *Fig.* 65. For this application a high starting torque is required to advance several sets of duplicated sheets from a roll to a receiving bin. The motor is a 1/75-horsepower, 2-pole universal type. Starting load is 12.5 oz-ft and the input current is 1 amp at 115 volts. Full-load speed is 115 rpm, obtained through planetary gearing with the motor operating at more than 15,500 rpm. This interesting motor is built in a die-cast aluminum frame and weighs little more than one pound.

Polyphase Motors: If a power supply could be chosen that would be ideal for the electrical design of motors, polyphase current would be such, because a stator field can be wound to have imaginary poles rotating in a specific direction and at a definite speed. This is not true for other power supplies. In a squirrel-cage induction polyphase motor no mechanical devices such as centrifugal switches, commutators or slip rings are required either for starting or running torques. For a three-phase motor, *Fig.* 39 shows how this simulated pole rotation is obtained from the current reversals.

Usually, three-phase is the standard power for industrial plants, although two-phase supply is employed in some places. Two-phase motors operate similarly to three-phase designs except that two sets of windings produce the rotational field instead of three and the current phase between the two is 90 electrical degrees instead of 120 as shown in *Fig.* 39. Polyphase motors cannot operate successfully interchangeably from 3-phase to 2-phase, being designed only for the specific power supply for which they are intended. Single-phase motors, however, can operate on either two or three-phase supply by connecting into any one phase. It is desirable though to keep the current balanced in a system. This may be done by connecting other single-phase loads into the remaining phase or phases.

Polyphase motors are more efficient, have better starting characteristics, and produce much higher torques in a given frame size than single-phase motors. They are more expensive in fractional and small integral-horsepower ratings, probably because they are not produced in the same volumes. The volume of production of fractional-horsepower motors results from their preponderance of use in domestic, commercial and office machines where only single-phase current is universally available, not because of desirable characteristics. Basically, the polyphase induction motor is simpler in construction; other factors being equal, it would be less expensive. As much as 40 to 50 per cent more power can be designed into a given frame size, conserving materials, effecting more compact designs, and simplifying application where space is at a premium.

Differing from single-phase motors, polyphase motors are of only three general types: squirrel-cage, wound-rotor (slip-ring), and synchronous. These are illustrated schematically in *Fig.* 66. Two types of synchronous motors are included; the true synchronous motor has a wound rotor excited with direct-

—data. Courtesy Westinghouse Electric Corp.

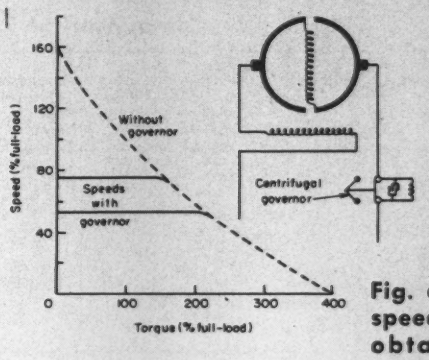
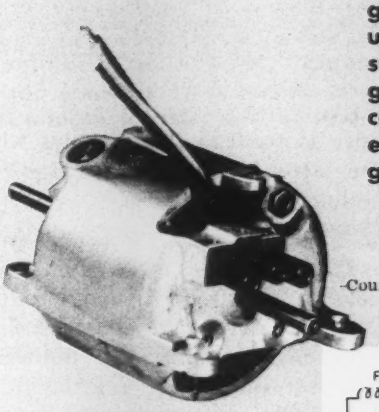


Fig. 62—Characteristic speed control curves obtainable from a governor - controlled universal motor. As shown in the diagram, a resistor and capacitor are usually employed across the governor contacts



—Courtesy, Signal Electric Mfg. Co.

Fig. 63 — Governor-controlled, reversible universal motor for operating motion-picture projectors and other similar equipment. Rated at 1/8-1/6 horsepower at 115 volts, the motor has a cast-aluminum frame and resilient mounting

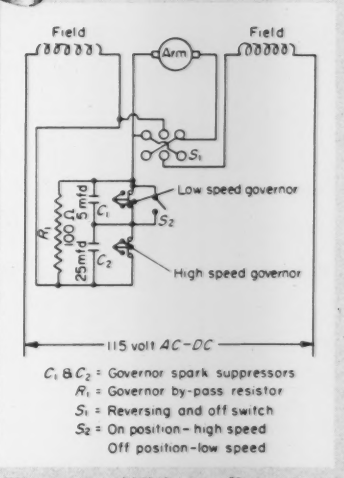
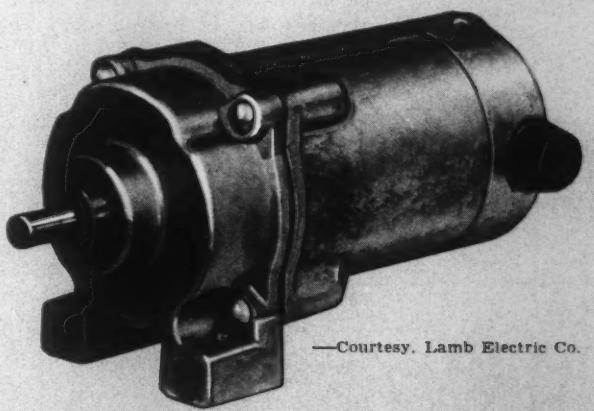


Fig. 64—Wiring diagram for two-speed governor-controlled, 4-lead reversible universal motor



—Courtesy, Lamb Electric Co.

Fig. 65 — Universal gearmotor designed especially for driving an office billing machine develops high torques at low speed. Motor is lightweight and small, meeting requirements of the application

Table 19—Comparison of Polyphase Squirrel-Cage Motor Designs

Design of Motor	Slip at Full Load (%)	Locked-Rotor Current§ (% full load)	Starting Torque (%)	Breakdown Torque (%)	Characteristics of Design	Typical Motor Applications
A	<5	660	185	270	High starting current, high overload torque	Industrial machines
B	<5	600	185	225	Normal torque, low starting current	General-purpose industrial machines
C	<5	600	250	200	High starting torque	Pumps, conveyors, etc.
D	>5	600	250–400	250–400	High slip and starting torque	Punch presses and high inertia loads
F†	<5†	†	125†	...	Low current, starting and max. torques	Pumps, etc.

† No Design F motors are available under 30 hp. Starting currents for Design F are less than other designs. Breakdown torque for Design F are lower than other designs.
§ Based on a 5-hp motor.

current, the reluctance motor has salient poles which are nonexcited. The latter appears like a squirrel-cage rotor but has slots cut to form poles.

SQUIRREL-CAGE MOTORS: Where a constant-speed, but not synchronous, motor or a multispeed motor having definite speeds is required, the squirrel-cage motor is employed. In a squirrel-cage multispeed motor, however, the speeds obtainable are limited to whole-number ratios resulting from regrouping of the field poles. Squirrel-cage motors are the general-purpose motors for industrial-drives, *Fig.* 67.

Squirrel-cage motors have been classified into design groups according to their torque, current and slip characteristics. These NEMA designs are briefly summarized in TABLE 19 which lists characteristics and typical applications for *A, B, C, D,* and *F* Designs. All have less than five per cent slip with the exception of Design *D* which has more than five per cent. These slips are grouped into three divisions, 5-8, 8-13, and 15-20 per cent. Also, all designs have low starting current except Design *A* which has a higher value. The designs are characterized by

DESIGN *A*: Normal starting torque, extra-high overload torque, high starting current. For high peak running loads

DESIGN *B*: Normal starting torque, high overload torque (200-275 per cent) low starting current. For general purpose applications

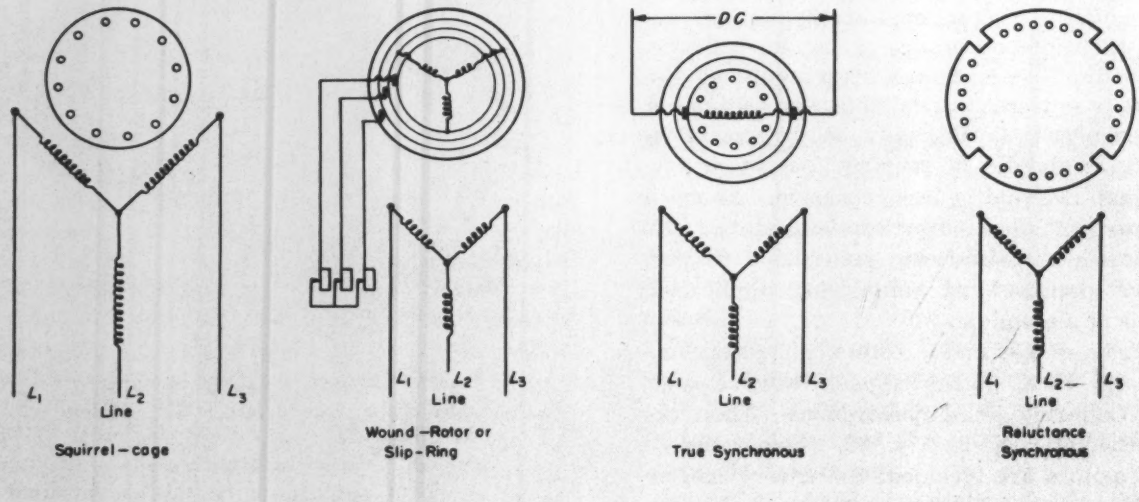
DESIGN *C*: High starting torque (200-250 per cent), medium overload torque (190-225 per cent), low starting current. For starting heavy loads. Not suitable for frequent starting applications

DESIGN *D*: Extra high starting torque (275 per cent), low starting current. High slip for high inertia loads, flywheel applications and reversing duty

DESIGN *F*: Low breakaway and overload torques (125 and 135 per cent, respectively), made only in sizes of 30 horsepower and larger for driving blowers, etc.

Comparative speed-torque curves for the four designs are shown in *Fig.* 68. These curves are merely for comparative purposes, showing general characteristics of each type. Design compromises are employed to avoid high starting current or low starting torque. If higher resistance is employed in the rotor, torque is increased but so is slip, and efficiency is

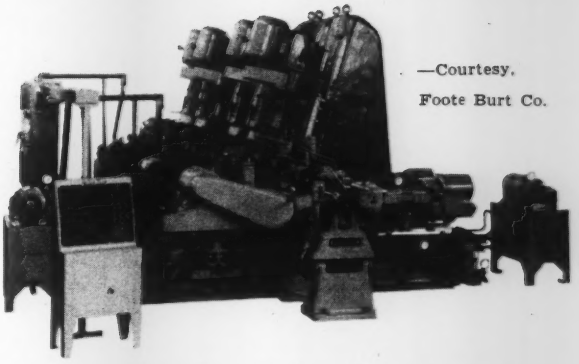
Fig. 66—Schematic representations of three basic types of polyphase motors, including both true and reluctance synchronous motors



sacrificed. Design *C* achieves low starting current and high starting torque at the expense of full-load power factor. Design *D* has low starting current and high starting torque at the expense of higher slip and lower efficiency. Standard NEMA values for locked-rotor current, locked-rotor torque, and breakdown torque for each design of motor and speed are listed in TABLE 20.

Multispeeds: Two or four definite speeds are obtainable from specially wound field coils in squirrel-cage motors to provide constant-horsepower, constant-torque or variable-torque characteristics. With one field winding, the poles may be doubled by regrouping the connections. This always gives a 2:1 reduction. In constant-torque motors the horsepower at the low speed is half that of the high-speed. For constant horsepower, the torque is doubled at the low speed. Variable-torque motors, for example, may be designed to produce one-half as much full-load torque at the low speed as at the high, giving one-quarter as much horsepower. These three conditions of torque speed relations are indicated in *Fig.* 69. The curves are from data for a basic 10-horsepower, 1750-rpm squirrel-cage motor. With two-winding multi-speed motors, the speeds are not limited to the 2:1 ratio. Any desirable whole number ratios obtained from regrouping 2-pole, 4-pole, 6-pole, 8-pole, etc., motors would give speed ratios of a multispeed motor; this motor is complicated to the extent of having two windings, one of which is always idle while the motor is running at the speed of the other. Its ability to run at speeds other than the 2:1 ratio, however, makes it an extremely useful drive. Control is also less expensive.

Four speeds are obtainable from the two-winding motor by regrouping each winding, halving its respective speed. Thus, it is possible to obtain speed ratios of 1, 2, 3, and 6 from one motor, for example, 3600, 1800, 1200, and 600 rpm synchronous speeds on



—Courtesy, Foote Burt Co.

Fig. 67 — Totally-enclosed fan-cooled Westinghouse squirrel-cage motors driving multiple spindles on a section of a station type of automatic transfer drilling and tapping machine

60-cycles. Also, speed ratios of 1, 1½, 2, and 3 would give 1800, 1200, 900, and 600 rpm from 4 and 6-pole motors having split connections. Other ratios are possible within the mechanical limitations of poles but it is necessary, if four speeds are desired, to avoid having the second winding with twice the number of poles as the first winding. Then only three speeds would be available, one speed being obtainable from two different winding connections.

As in the two-speed single-winding motor, constant-horsepower, constant-torque or variable-torque characteristics are available depending on the electrical design of the motor. To illustrate the speed characteristics, a set of curves for a constant-torque, 4-speed motor is graphed in *Fig.* 70. This is basically a 10-horsepower, 1750-rpm, 60-cycle polyphase motor. The full-load speeds are 1750—1160—875—580 which gives 10—6.7—5—3.3 horsepower for constant torque conditions, the horsepower being proportional to the speed under constant-torque conditions. The pole con-

Table 20—Polyphase Squirrel-Cage Motors Continuous Rating*

(50 and 60-cycle)

Locked-Rotor Torque†								Breakdown Torque†							Starting Current**	
Design A and B				Design C			Design D	Design B‡				Design C			Design B, C, D	Design B
2-Pole (%)	4-Pole (%)	6-Pole (%)	8-Pole (%)	4-Pole (%)	6-Pole (%)	8-Pole (%)	All Motors (%)	2-Pole (%)	4-Pole (%)	6-Pole (%)	8-Pole (%)	4-Pole (%)	6-Pole (%)	8-Pole (%)	60-cycle (amp**)	50-cycle (amp**)
...	...	...	150	...	...	...	275	...	...	...	250	...	...	...	12	14
...	...	175	150	...	...	...	275	...	...	275	250	...	...	...	18	21
...	275	175	150	...	...	...	275	...	300	275	250	...	...	...	24	28
175	265	175	150	...	...	...	275	275	300	275	250	...	...	...	35	40
175	250	175	150	...	...	...	275	250	275	250	225	...	...	...	45	50
175	250	175	150	...	250	225	275	250	275	250	225	...	225	200	60	70
150	185	160	130	250	250	225	275	225	225	225	225	200	200	200	90	105
150	175	150	125	250	225	200	275	215	215	215	215	190	190	190	120	140
150	175	150	125	250	225	200	275	200	200	200	200	190	190	190	150	175
150	165	140	125	225	200	200	275	200	200	200	200	190	190	190	220	255
150	150	135	125	200	200	200	275	200	200	200	200	190	190	190	290	335
150	150	135	125	200	200	200	275	200	200	200	200	190	190	190	365	420

ased on NEMA Standards.
er Cent Full-load values.
esign A Breakdown Torques are greater than those listed for Design B.
arting current, based on locked-rotor conditions for 220-volt motors. For other voltages current is inversely proportional to voltage.

Fig. 68—Comparative speed-torque curves for Designs, A, B, C, D and F of Squirrel-cage motors

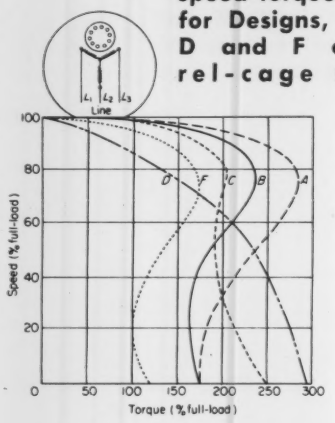
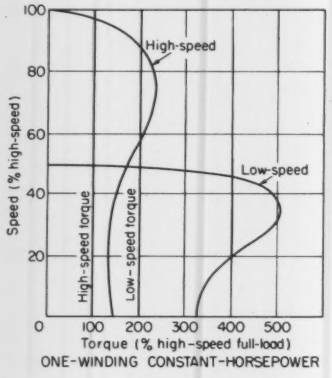
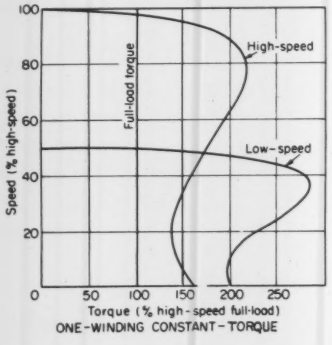
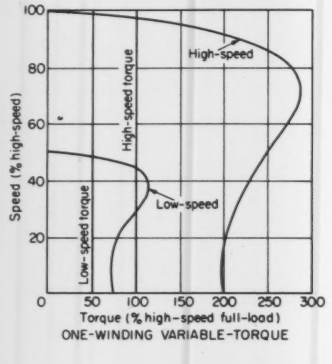


Fig. 69 — Speed-torque characteristics for one winding, two-speed motor designed for constant horsepower, constant torque and variable torque

—Data, courtesy Louis Allis Co.







nections for this motor are 4-8 and 6-12.

To obtain adjustable varying-speed control, not specific speeds obtained by field-pole combinations, resistors are placed in series with the three lines of the squirrel-cage motor as indicated in *Fig.* 71. With this arrangement, the voltage impressed on the field windings may be adjusted. The speed range can be anything from zero to synchronous. Referring to *Fig.* 71, it can be seen that the speed is sensitive to the load requirements, consequently this type of control works best on a fixed or known type of load Because of the power consumption of the series resistors, this system is usually restricted to horsepower ratings less than 25 hp.

To reduce starting currents drawn by squirrel-cage motors, reduced voltages obtained from taps on an autotransformer are sometimes employed during the acceleration period. Two or more taps are usually provided for the voltage increments before full-line voltage is applied to the motor terminals. This method is used where the current drawn from the line would be objectionable from the standpoint of the power supply system. It is also useful for cushioned acceleration when starting under low-load conditions.

Another method of starting, which has become popular recently, is the part-winding method. This obviates the autotransformer and is effected by having additional leads on the motor, dividing the field windings. The starter employed usually has a timer for connecting the windings in the required sequence. This method minimizes voltage fluctuations in the line during the starting period.

WOUND-ROTOR MOTORS: To provide adjustable varying-speed drives or to improve starting conditions, wound-rotor motors are employed in polyphase systems. Variable speeds are obtained through the insertion of resistors in the armature circuit. Speed regulation, however, is difficult under light-load conditions. To improve starting conditions over that of a squirrel-cage motor, a relatively large resistor is inserted in the rotor windings to reduce the current

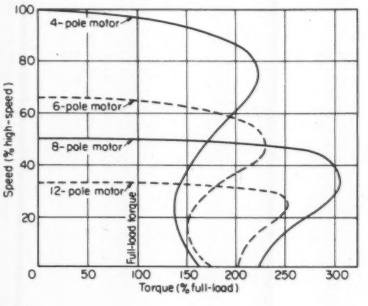


Fig. 70 — Curves for multispeed motor having constant torque for full-load values at all speeds. The 4-pole winding reconnects to 8-pole, and the 6-pole to 12-pole

—Data, courtesy Louis Allis Co.

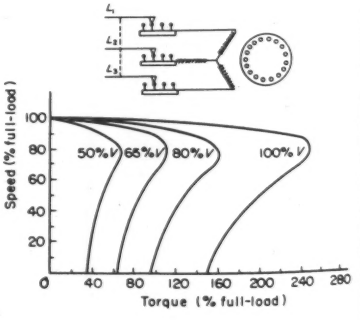


Fig. 71 — Speed control curves for a squirrel-cage motor using primary resistors

—Data, courtesy Westinghouse Electric Corp.

and provide a high starting torque. When the motor attains its speed, the rotor circuit is opened and the slip-ring terminals are short circuited. This type of motor is also employed as a synchronous drive by reconnecting and applying direct current to the secondary windings when the rotor has reached speed.

Possibility of speed control with wound-rotor motors, however, accounts for its major applications. Usually, a 2:1 variation is obtainable and greater reductions are possible if speed regulation is not critical. *Fig.* 72 illustrates how the speed-torque may be varied with resistances in the rotor circuit. Curve 1 has maximum resistance and curves 2 to 11 have decreasing amounts of resistance. The upper curves are for a typical wound-rotor motor with various balanced values of resistance in the secondary circuit. At speeds above 50 per cent synchronous and with the motor well loaded, the speed is not as sensitive to load changes as for lower speeds and loads, providing better speed regulation.

These curves are somewhat similar to those of a dc shunt motor operating with resistance in the armature circuit. As resistance is inserted in the secondary circuit, the speed regulation becomes worse. In view of this fact, this speed control system works best on constant-load applications. This system does not work too well for light loads and speeds less than 40 per cent of synchronous speed. For all practical purposes, a speed range of approximately 2 to 1 is about the maximum.

In *Fig.* 72 is also illustrated how insertion of resistance can provide smooth starting of heavy inertia loads or how high locked-rotor torque may be provided with low current. When running conditions prevail, the rotor windings are short circuited. Curve 12 in *Fig.* 72 shows the secondary short circuited. TABLE 21 shows the breakdown torque for wound-rotor motors for 50 and 60-cycle motors.

In considering the useful features of wound-rotor motors, the need for these should be weighed against obtaining satisfactory operation by alternative methods. Wound-rotor motors require additional external control elements, complicating their application and increasing costs. In addition the motor itself costs over twice that of a comparable squirrel-cage motor, but is about three times as much in the smaller sizes. Also, the motor is larger, frequently requiring one size larger frame than the squirrel-cage counterpart. Maintenance of the slip-rings and controls in service is another factor to consider. It should be justified economically by added performance features.

Table 21—Breakdown Torque Wound-Rotor Motors †

Motor Size (hp)	Breakdown Torque* 4-Pole (%)	6-Pole (%)	8-Pole (%)
1	...	...	250
1½	...	...	250
2	275	275	250
3	275	275	250
5	275	275	250
7½	275	250	225
10	275	250	225
15	250	225	225
20-200	225	225	225

† From NEMA Standards for 50 and 60-cycle motors rated for continuous duty.
* Breakdown torque percentage of full-load torque.

SYNCHRONOUS MOTORS: These motors are less economical than other motors except in large sizes, possibly above 100 horsepower. When employed in smaller sizes, they are either for maintaining exact synchronous speed regardless of load or for improving power-factor conditions in a plant or installation. In machine applications, therefore, they are mostly employed for timing controls. Polyphase synchronous motors are produced commercially in ratings of 1/750-horsepower and larger. General-purpose synchronous motors are standardized up to 200 horsepower. Other types are rated up to 15,000 horsepower.

The discussion of synchronous motors in the pre-

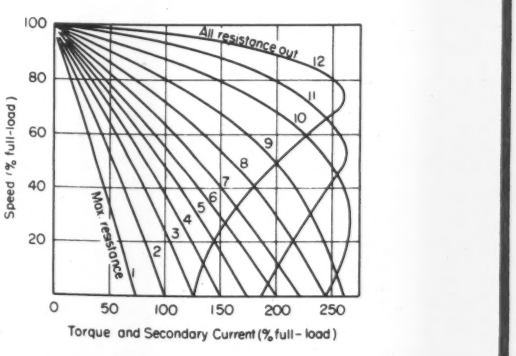


Fig. 72—Speed-torque and current curves for a typical wound-rotor motor with resistances in the secondary. Curve 12 shows the secondary short circuited, curve 1 having maximum resistance

—Data, courtesy Louis Allis Co.

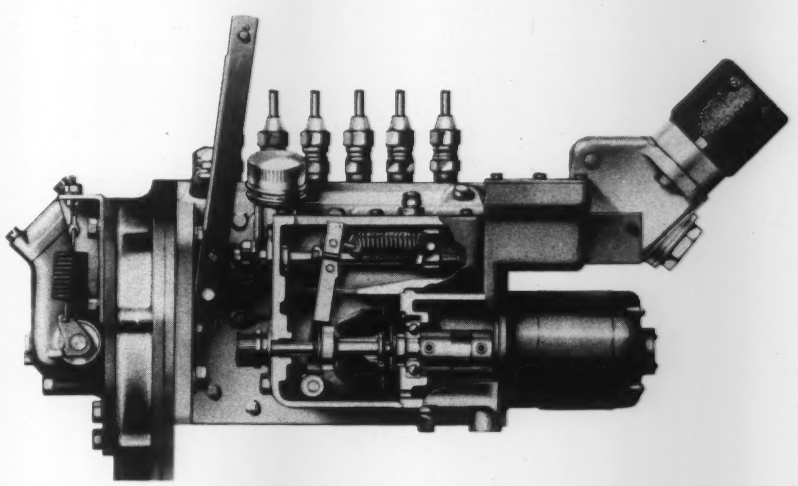
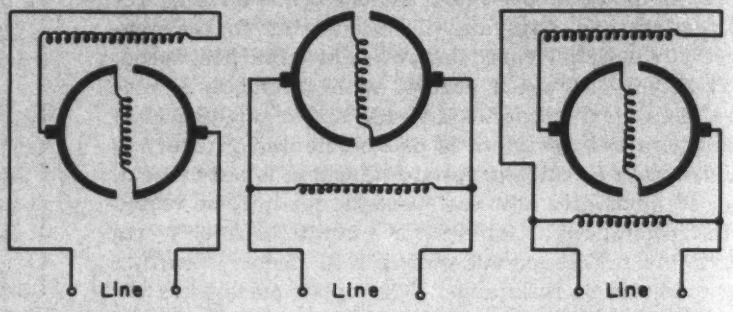


Fig. 73—Flange mounted Bodine synchronous motor provides reference speed for diesel engine driving a generator through a hydraulic coupling

—Courtesy, Waukesha Motor Co.

Fig. 74—Schematic representation of the principal features of the three basic types of dc motors



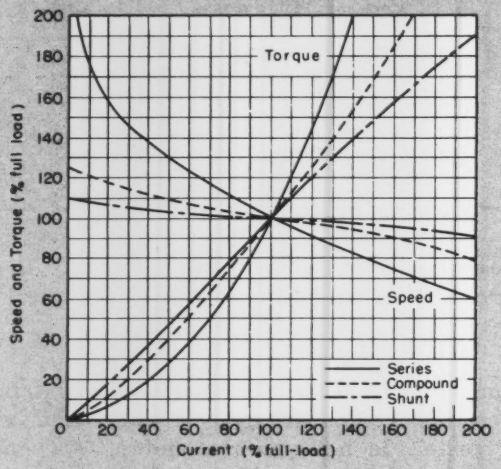


Fig. 75 — Speed and torque characteristics for dc motors plotted against current for integral-horsepower motors

—Courtesy, Louis Allis Co.

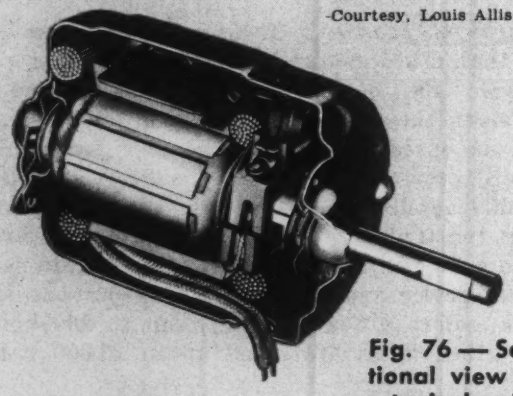
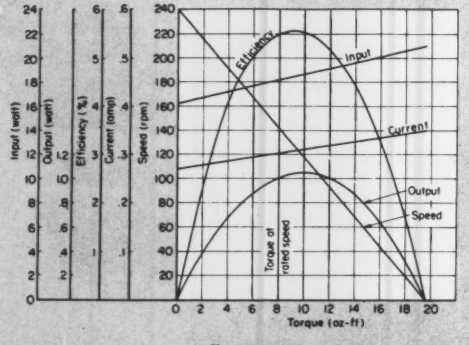


Fig. 76 — Sectional view of a typical series motor for low-voltage applications on automobiles, etc.

—Courtesy, Redmond Co. Inc.



—Courtesy, Lamb Electric Co.

Fig. 77—Curves for series motor designed to have straight-line speed-torque characteristics for elevator leveling and tension devices

ceding section on single-phase motors applies generally to polyphase types. Usually, however, they are either true synchronous motors with dc supplied to the armature windings or reluctance motors with salient poles. These salient poles may be formed by milling sections from the surface of a squirrel-cage rotor to form teeth. All synchronous motors are accelerated electrically by another form of motor characteristic. True synchronous motors may start as a wound-rotor motor, for instance, and reluctance motors as a squirrel-cage induction motor. In the case of the former, controls are utilized for switching to synchronous operation. For the latter, the motor inherently alters its characteristics and virtually jumps into synchronism by itself.

Synchronizing or pull-in torque must be sufficient to accelerate the motor from its induction-run slip to full synchronism. This acceleration must take place before the armature pole has slipped less than halfway to the next following field pole. Otherwise the torque would be decelerating and the motor would not pull into synchronism. For this reason, synchronous motors are started wherever possible without load or with a minimum load. Also, to approach synchronism as far as possible, starting characteristics are designed to give minimum slip but with sufficient torque. Inasmuch as one of these is obtained at the expense of the other, the slip-torque characteristics are developed as a compromise.

These torque-slip problems in accelerating motors to synchronous speeds may give rise to the possibility of starting as a high-slip, high-torque, four-pole motor and reconnecting to six or eight poles when synchronism is reached. Because torques are sacrificed in nonexcited synchronous motors, these motors are usually rated at half to one-third that of an induction motor in the same frame size.

In *Fig.* 73 is a synchronous motor controlling a master governor for a diesel engine driving an alternating-current generator through a fluid coupling. To maintain a desired frequency regulation of plus or minus 1¼ cycles from no load to full-load requires controlling the engine speed in relation to the generator regardless of the fluid-coupling slip. The master governor utilizes a 3-phase, 1/40-horsepower syn-

chronous motor as a driving means to provide a governor speed equivalent to the alternator speed. To control the engine speed for the desired generator frequency, the governor actuates the fuel-injection pump rack of the engine.

High-Frequency Motors: Although not covered specifically in this article, high-cycle motors are effectively employed to increase motor speeds above 3600 rpm, the limit of 60-cycle induction motors. Alternating current with frequencies of 100, 180, 400, etc., producing maximum speeds for 2-pole motors of 6000, 10,800 and 24,000 rpm, respectively, are utilized to advantage in woodworking machines, in aircraft, etc.

For a given horsepower, a motor that operates at a higher speed than another is smaller and lighter in weight. In applications such as aircraft where these high speeds are not required as output speeds, gearmotors reduce the speed to desired values at a saving in both weight and space. For aircraft, the power supply is generated at the frequency desired without involving additional auxiliary equipment.

In industrial applications, however, it is necessary to employ relatively expensive frequency converters such as motor-generator sets. These convert the 60-cycle power supply to the desired frequency. Both reduced size of the motor and the higher speed prove advantageous. High-speed spindles are direct connected, applying the power at the point of utilization without intermediate transmission units. This provides for compactness and flexibility in design. Where multiple heads are involved, the decreased size and direct-connected motor often make possible compact designs which would otherwise be impracticable. Also, more versatile and more convenient machines are possible.

Direct-Current Motors: Direct-current power supply is definitely limited inasmuch as it cannot be transmitted economically at usable voltages over distances such as from a central station to an industrial area. Alternating-current power, however, is transmitted economically at high voltage and stepped down through simple distribution transformers to a desirable usable voltage near the point of application. Direct current, except in a few localities is not available as purchased power. Plants, such as steel mills, may generate their own dc power.

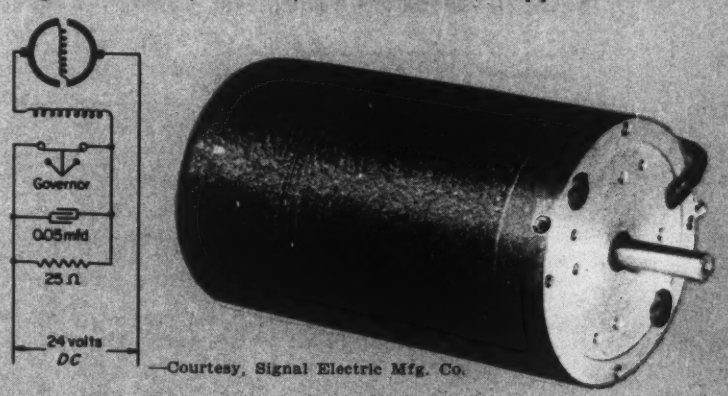
Distinct fields are served by dc motors and some of them could not be served with ac motors, particularly portable or mobile equipment utilizing stored power from a battery. Automobiles and portable recording instruments are typical. Also, even at the expense of converting alternating current, direct-current motors are employed in adjustable-speed drives, giving excellent speed adjustment over wide ranges under varying loads.

Three types of direct-current motors are built, each having variations to alter the electrical characteristics. These types—series, shunt and compound—are illustrated schematically in *Fig.* 74. The name of each is descriptive of the electrical relation between the field and armature circuits, referred to as primary and secondary, respectively. Distinct characteristics make them useful for different types of applications. The series motor has its field and armature circuits connected in series, i.e., the same current flows through both circuits. Therefore, the current values in both are always the same. The shunt motor has the circuits in parallel connection. In this motor, the field is shunted across the line so that the primary and secondary windings each have line voltage. The current flowing in each, however, is independent of the other. The compound motor has both series and parallel connected fields to combine the features of series and shunt motors, the degree of compounding determining the performance characteristics.

In applying direct-current motors, consideration should be given to adequate motor characteristics if rectified power is utilized. Because of additional motor heating resulting from the voltage ripple, which may be as high as 40 per cent, a motor in a frame larger is frequently required.

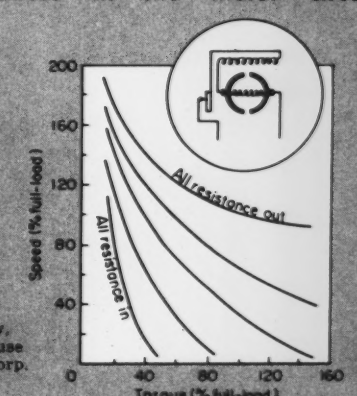
Shown in *Fig.* 75 are comparative speed and torque curves for integral-horsepower dc motors. It should be noted that the current is plotted as the independent variable. The compound motor could have almost any values desired for torque and speed between the limits of the series and shunt motors.

Fig. 78—Governor controlled series motor operates at constant speed regardless of load. This lightweight compact motor is designed for face mounting in aircraft, mobile, and industrial applications

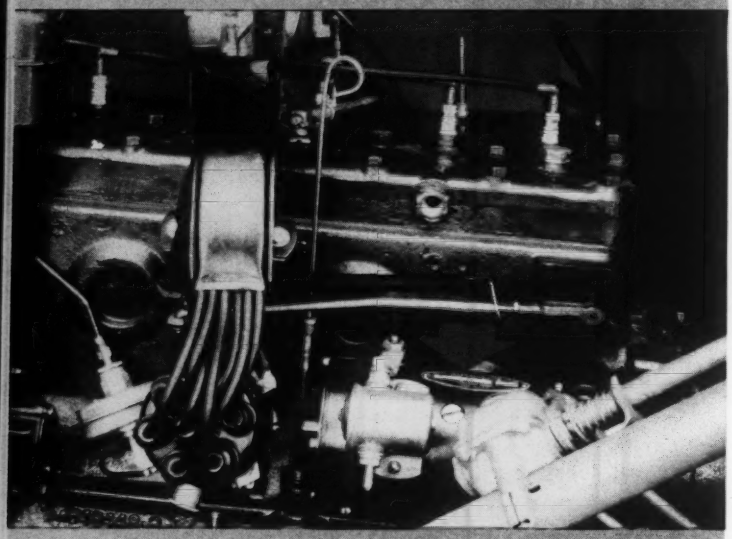


—Courtesy, Signal Electric Mfg. Co.

Fig. 79—Characteristic speed-torque curves for a series motor obtained by inserting resistances in the motor circuit

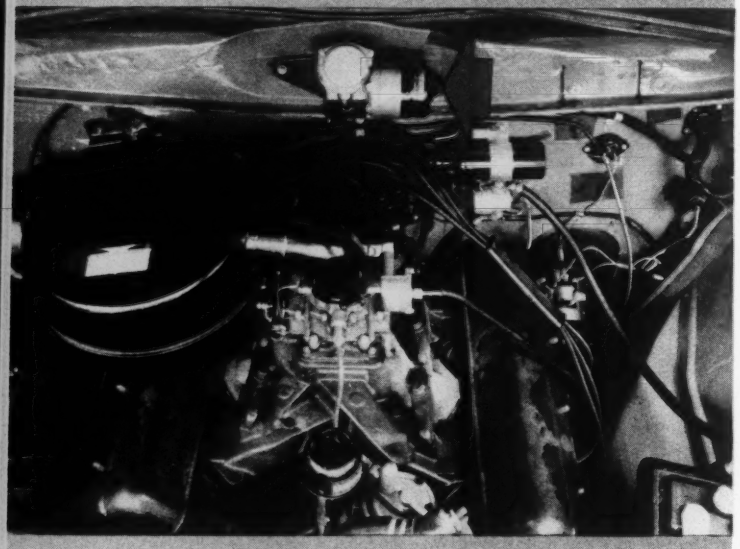


—Courtesy, Westinghouse Electric Corp.



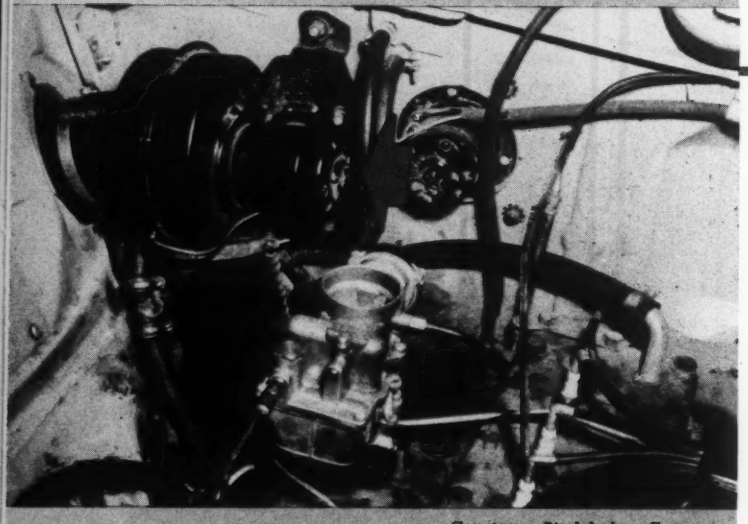
—Courtesy, Studebaker Corp.

Fig. 80 — Series-wound motor, employed for automotive engine starting



—Courtesy, Studebaker Corp.

Fig. 81—Windshield wiper driven by a Redmond series-wound motor



—Courtesy, Studebaker Corp.

Fig. 82—Heater fan powered by series type motor

Standard ratings for speeds have been assigned to constant-speed dc motors. These are summarized in TABLE 22. Also included in the table are the maximum speeds obtainable by field weakening of shunt motors which will deliver full rated horsepower for integral-horsepower motors. In referring to this table it should be noted that motors smaller than 1 horsepower at 1800 rpm are fractional-horsepower motors. Thus, 1-hp at 1750 rpm, ¾-hp at 1150 rpm, and ½-hp at 850 rpm are classified as integral-horsepower motors. Adjustable speed ratios of 3:1, 4:1 and 6:1 obtained with armature current control have been standardized for specific motor speeds to include ½ to 20 hp at 115 volts and ½ to 150 hp at 230 volts.

General-purpose integral-horsepower dc motors are usually designed to have a service factor of 1.15. This means that a motor may be loaded continuously at 115 per cent of its rated horsepower without overheating when operated at its rated voltage.

Series Motors These motors, *Fig.* 76, are suitable for applications requiring high starting torques but which have a relatively constant load. Because of its runaway characteristics, the motor is always direct connected to its load except possibly fractional-horsepower motors where windage and friction restrict excessive speeds. Speed is inversely proportional to load and, up to the point of saturation of the field, the torque varies as the square of the current. Above the point of saturation, the torque varies more nearly as the current.

Series motors are employed as traction motors, hoist motors, crane motors, automotive starting motors, and drives for similar applications. The motors are well suited for operations requiring more than one motor to drive the load. Then the motors are usually connected in parallel, the load being readily divided equally between identical motors because of the extreme drooping speed characteristics of the motors. One set of starting contactors is usually used to simplify control and assure that each motor receives identical potentials.

An interesting set of curves is shown in *Fig.* 77 for an elevator leveling motor. This motor has a straight line torque-speed characteristic and is capable of with-

Table 22—Standard Ratings for Constant-Speed DC Mot

Horsepower (hp)	Voltage (v)	Full-Load Speeds (rpm)	Max. Spe (S_m/S_f
Fractional (1/20–1*)	32, 115, 230	3450, 1725, 1140, 850	
Integral (1/2–40†)	115	3500, 1750, 1150, 850	2:1**
Integral (1/2–40†)	230	3500, 1750, 1150, 850, 690, 575, 500, 450, 400, 350, 300, 250, 200, 150, 100	2:1**

* Excepting integral-horsepower ratings, e.g., ½-hp, 850 rmp.

† Excepting fractional-horsepower ratings, e.g. 1-hp, 3450 rpm.

§ Maximum speeds of shunt-wound motors obtained by field-weakening at wh rated horsepower can be delivered. Motors having speed ratios of 3:1, 4:1 6:1 are considered adjustable-speed motors.

** Excepting: 3500 and 1750 rpm motors and 1150 rpm motors > 5 hp. Th max. speeds are 3500, 2190 and 1725 rpm, respectively.

standing stalled conditions continuously. A 2-pole gearmotor, it is rated at ¾-watt output at 140 rpm, operating on 60 volts dc. This type of motor is also applied as a torque motor on tensioning devices.

Reversing and Braking: Series motors may be plug reversed by reversing the connections to the armature (secondary) circuit. Although the primary windings may be reversed instead to change the direction of rotation, the other practice is invariably followed. When plug reversals are not needed, terminals may be supplied for reconnection of the windings. Conventional dynamic braking, i.e., disconnecting from the line and inserting a resistance, is not employed for series motors because generator action of the armature might destroy the residual magnetism in the field. Instead a resistance is placed in series with the armature and field and the field connections reversed. This induces current in the field in the same direction and generator action is obtained, braking the motor.

On loads such as hoists which might be overhauling, another system of dynamic braking is often employed. It consists of inserting a resistance in series with the field and connecting across the line. Another resistance is inserted across the field windings which are disconnected from their series relation with the field. This provides a reverse drive but brakes an overhauling load.

Speed Control: Small series motors are often employed as constant-speed drives, frequently having more than one speed setting. To retain high torque characteristics for these specific speeds, make-and-break contacts operated by a centrifugal governor are employed in the same manner as in universal motors. Such a series motor is shown in *Fig.* 78 together with a simplified schematic diagram.

By inserting series resistance in the armature circuit, adjustable varying-speed control is obtained. Characteristic curves for such a control are shown in *Fig.* 79. Speed regulation is not good, the speed varying considerably with a small change in load. Thus, constant loading is required. Series resistors on this type of motor are employed mainly for starting purposes.

Automotive auxiliary drives, such as starters, window operators, top lifters, windshield wiper motors, blower motors, etc., are of the series type. Sufficient power for their slow-speed operation is adequate from all these motors with the exception, perhaps, of the starter motor. It develops as much torque as is possible from present-day 6-volt batteries and is adequate except for unusual conditions. Typical series motors used for starter, windshield wiper and blower are shown in *Figs.* 80, 81, and 82.

Adjustable-speed drives of the series variable-voltage type, *Fig.* 83, employ an ac motor to drive a dc series-wound generator. Output of the dc generator is connected directly to a dc series motor. In this system, the motor current goes through both the generator field and motor field. By means of a speed-adjusting rheostat, more or less of the motor current is shunted around the generator field. This determines the output voltage of the series-wound generator. An inherent characteristic of the shunt type motor is that as the shunt fields heat up, the speed of the machine increases. With a series type of machine, however, there is practically no change from hot to cold operation because of the much lower percentage of resistance in the fields. This is a simple type of Ward-Leonard drive and has fairly flat operating curves, *Fig.* 84. The system is inherently stable since heavy current loads flow through the generator field and tend to boost the voltage to maintain flat speed characteristics. Recent improvements and developments in electronic controls, however, have minimized the economic advantage previously held by this drive.

Up to 300 per cent of full-load running torque is available in this drive for starting. A 10:1 speed range can be obtained from a single rheostat, giving, for instance, a range of 175 to 1750 rpm from a 1750 rpm motor.

Shunt Motors These are the general-purpose constant-speed dc motors. Starting torques do not equal those for the series motor, usually being limited to about 200 per cent full-load torque by the use of starting resistors. Ability to maintain fairly constant speed from no-load to full-load conditions and useful-

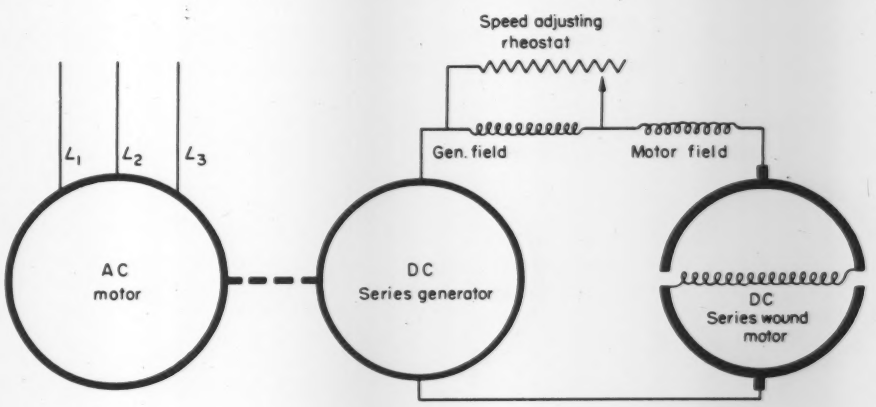


Fig. 83—Series variable-voltage type of adjustable-speed drive from an ac power supply

—Courtesy, Westinghouse Electric Corp.

ness as adjustable-speed motors make them invaluable for machine tools and general machinery drives.

Standard speeds for shunt motors are listed in TABLE 22 according to voltage and horsepower. Although speed regulation of shunt motors is not as good as that for ac motors, the maximum differential between full-load and no-load speeds is 25 per cent for fractional-horsepower motors. Maximum regulation values for these motors are listed in TABLE 23. Many shunt motors, however, have speed-regulation values between 5 and 12 per cent, making them particularly useful for constant-speed and adjustable-speed drives. Frequently, interpoles are inserted in the motor field, improving the motor characteristics. These interpoles, placed between the main field poles are wound in reverse to pull the field flux into place, minimizing stray flux and improving commutation.

If two or more motors are to be connected in parallel to drive a load, it is necessary that the motors have identical speed-regulation characteristics. Because the speed-torque curves of shunt motors are fairly flat, the motors do not adjust themselves to load division as readily as series motors. For parallel operation the motors are either adjusted by brush shifting or by the addition of field turns to increase the field strength until the characteristics are balanced.

Plugging and Braking: For reversing the direction of rotation of a shunt motor either the armature or field winding is reverse connected. In plug reversals, it is necessary to insert resistances in the armature circuit to limit the current to safe values. Inductive controls for plugging, wherein relays operate in the control circuit when the flux decays to control the armature current, are employed to advantage for rapid reversals.

When it is not necessary to hold the load after the motor is stopped, dynamic braking is frequently useful to assist in decelerating the motor. For some applications this is preferable to plug stops because there is less shock to the system. In dynamic braking, the armature is disconnected from its power supply and a resistance inserted across the windings. To increase the braking effort as the motor slows down, this resistance may be cut out in steps. Also, the field strength may be increased to further aid braking as slower speeds are approached.

Speed Control: Three methods of speed control employing shunt motors are available for general use. They are obtained by armature series resistance, by field resistance, or by adjustable-voltage from a motor-generator set.

By the insertion of series armature resistance, the speed of a shunt motor may be reduced from its base rated speed downward. Typical characteristics of a motor with this control are shown in *Fig.* 85. Speed regulation becomes worse as resistance is increased in the armature circuit. In general a 2:1 speed range

Table 23—Speed Regulation of Shunt-Wound Motors*

Motor Rating (hp)	Full-Load Speed (rpm)	Speed Regulation (max. %)	No-Load Speed (max. rpm)
1/20-1/8	1725	20	2040
	1140	25	1710
1/6-1/3	1725	15	1980
	1140	20	1370
1/2-3/4	1725	12	1930
1/2	1140	15	1310

* Based on NEMA Standards. Maximum speed regulation values are standardized by NEMA. It is the percentage change in speed from no-load to full-load conditions with respect to full-load speed at rated voltage.

Fig. 84—Typical speed-torque curves for 6 voltage settings of a series variable-voltage adjustable-speed drive

—Courtesy, Westinghouse Electric Corp.

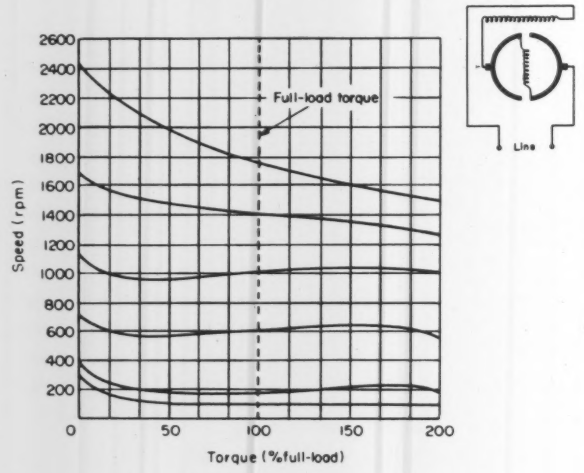
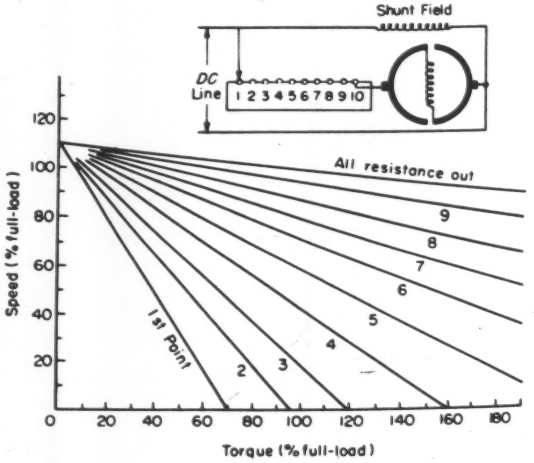


Fig. 85—Typical speed-torque curves for speed control of a shunt motor by varying armature series resistance

—Courtesy, Westinghouse Electric Corp.



is a practical limit. This type of control works best on a fixed or constant load. Series resistors, however, are employed mostly for starting purposes.

Speed control by field resistance employs a rheostat connected in series with the shunt field as shown in the diagram in *Fig.* 86. By insertion of more resistance, the shunt field strength is weakened to cause the motor speed to increase from the base or rated speed. Speed ranges up to 4:1 are obtained. As shown in *Fig.* 86, it can be seen that the speed regulation becomes worse as the field is weakened. In general, the speed range of 2:1 still produces fairly flat speed curves. For this reason, the system works well on applications having varying loads such as lathes or other machines where the load may fluctuate.

It should be noted that, as the field current is weakened, the motor speed increases, for this reason many controls use field protective relays to indicate when the shunt field circuit is open. Loss of field means unlimited speed due to the fact that the motor attempts to generate a counter voltage or emf and, with no field, can only do so by running faster and faster. In a fair size motor, if the field is lost, the speed increases until destruction of the motor results.

Adjustable-Voltage Drives: As discussed in the section on series motors, the adjustable-speed drive using a series generator, driven usually by an ac motor, and a series motor is one of the simplest systems for adjustable operation over a wide speed range. Because of the heavy current and the series type fields, this system is most satisfactory for single-direction operation. Another type of adjustable-voltage drive having more flexibility is shown in *Fig.* 87. A dc generator, driven by an ac motor, supplies power to a shunt motor. In this case the dc generator is of the shunt-field type.

In the sketch, *Fig.* 87, the fields are self-excited and, by means of a combination rheostat, the generator field is strengthened so that the motor speed goes from zero to 100 per cent. Then the motor field is weakened to produce higher motor speeds up to approximately 350 to 400 per cent of rated motor speed as indicated in the speed-torque curves in *Fig.* 87. The generator voltage can also be increased above rated voltage to increase the motor speed and horsepower output further. More up-to-date designs employ separately excited fields on the generator and motor. A small dc exciter is connected on the motor-generator set to provide energy for both the generator and motor fields. This system has increased flexibility since all control is initiated on the fields which are of smaller current magnitudes. In view of this fact, reversing-type contactors can be used to reverse the direction of the dc shunt motor rotation.

Modern ac to dc conversion systems make use of electronic and dry-type rectifiers for the power necessary to energize both the generator and motor fields. By means of convenient electronic circuits, a high degree of speed and load regulation can be maintained on these systems. Reliance Electric makes use of electronic-type exciters in their VS drive, *Fig.* 88. The Westinghouse drive uses a similar scheme and in the small horsepower ranges up to 5 hp., employs selenium type rectifiers for field excitation.

Basically, these systems all stem back to the Ward-Leonard system of ac motor and dc generator driving a dc motor. As mentioned before, the use of shunt-type fields involves smaller switching and control equipment than use of series fields. Some particular drives employ series stabilizing-type fields. The introduction of any series field, however, limits the drive to one-direction rotation rather than reversing such as many machines require.

One of the advantages of this system (Ward-Leonard or adjustable-voltage drive) is the ability to use the polyphase power entering a plant and to take advantage of the good speed characteristics obtainable from a dc drive motor. It should be noted that since the output of a dc generator is the same as that from any constant-potential dc source from the

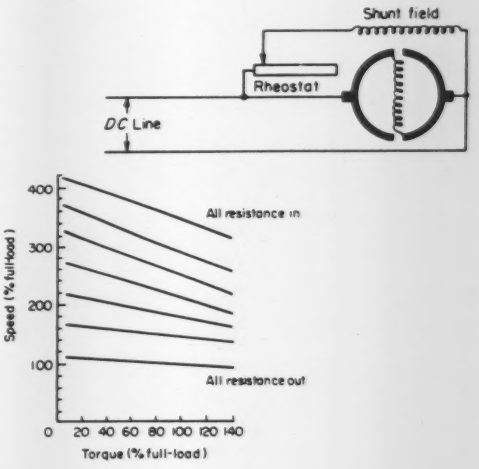


Fig. 86—Speed control of a shunt motor by field weakening giving increased speeds up to 2:1 with good regulation and up to 4:1 by sacrificing regulation

—Courtesy, Westinghouse Electric Corp.

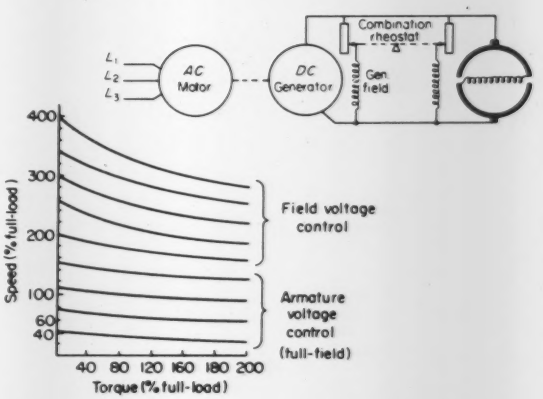


Fig. 87—Adjustable-voltage drive using shunt motor and motor-generator, showing wide speed range obtainable

—Courtesy, Westinghouse Electric Corp.

standpoint of ripple, the application of a dc motor is no different on an adjustable-voltage system than on a constant-potential system from the point of view of additional heating. From the standpoint of duty cycle, however, an adjustable-voltage system has the advantage that only as much voltage is generated as is needed for the motor. Consequently, duty cycle calculations show that the motor is used more efficiently and consequently smaller motors can be used.

In a constant-potential system, series resistors are used either for reduced speeds (heating is developed in the series resistors) or for high speeds by reducing the field excitation. In this case, the motor size is usually larger to develop the torque necessary at low speeds. In the adjustable-voltage system, higher speeds are obtained by increasing the armature voltages as well as by decreasing the field flux. Basically, the adjustable-voltage system is nothing more than an ac motor driving a dc generator which in turn supplies power to a dc motor.

A basic scheme is shown in *Fig.* 89 for an electronic type drive where ac power (single-phase) is converted by rectifier tubes (thyratron or ignitron). Through grid control, more or less current is made to pass through the dc motor armature and field circuits. By the addition of compensating circuits and regulating circuits, speed-torque curves similar to those shown in *Fig.* 90 are obtained.

An electronic drive does nothing more than control the amount of voltage and current to a dc motor. It should be noted that rectified 60-cycle ac voltage contains in some cases up to 40 per cent ripple. Since this ripple voltage also goes through the motor windings, it must be taken into consideration as additional heating on the motor. For this reason, the dc motor on a particular application may be slightly larger for an electronic drive than for an adjustable-voltage or constant-potential drive.

Another system of ac to dc conversion employs dry-type rectifiers. Either single or three-phase ac power is rectified to produce dc power which is fed to a dc motor. In general, this system is of the constant-potential type. Any adjustable-voltage control would be in terms of multitapped autotransformers on the ac end of the rectifiers. The ripple on a three-phase system is about four to ten per cent while on a single-phase system it runs as high as 40 per cent. This must be kept in mind in applying a dc motor. In making a comparison of the ripples it should be kept in mind that most electronic drives use single-phase power input.

Compound Motors: Having both shunt and series coils wound on each field pole, the compound motor combines the characteristics of shunt and series motors. Operating characteristics therefore lie between these two motors and are determined by the degree of compounding employed. Starting torque is lower than that for a series motor and higher than that for a shunt motor. With a minimum field strength held constant by the shunt field, however, there is no tendency to attain runaway speeds as in a series motor, depending on the degree of compounding. Because of the series characteristics, speed regulation is not good, varying considerably with load, and may be as high as 35 per cent in a standard motor.

Two types of compounding, short-shunt and long-shunt are represented in *Fig.* 91. In the long-shunt motor the shunt windings are connected across the line and have line potential. The short-shunt motor, however, has its shunt winding connected across the armature potential which is reduced by the potential across the series field.

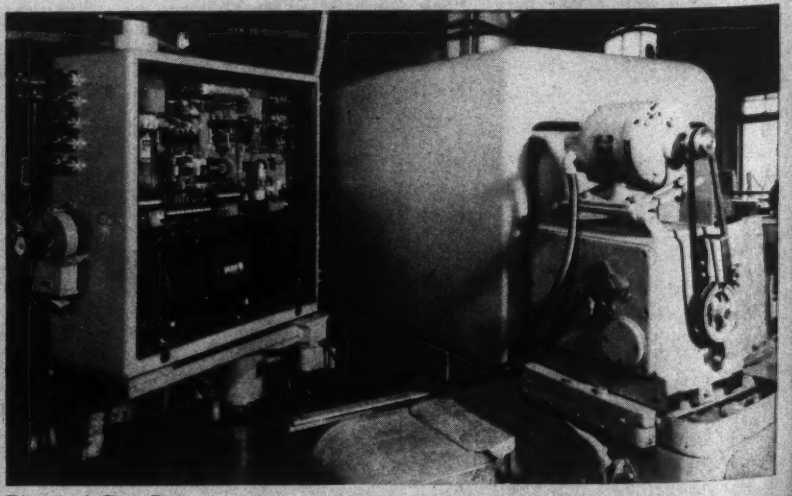


Fig. 88—Adjustable-speed drive for a pen-point grinder provides close speed regulation over wide operating range of grinder. Drive is 1-horsepower splashproof motor. Control cabinet containing power unit pivots from machine for ease in maintenance

—Courtesy. Reliance Electric & Eng. Co.

Maximum values of speed regulation have been assigned to fractional-horsepower motors for 1725 and 1140 rpm speeds and are listed in TABLE 24 together with their corresponding maximum no-load speeds. Integral-horsepower motors usually are designed to have 25 per cent regulation for general-purpose applications.

Compound-wound motors are suitable for across-the-line starting in sizes up to 5 horsepower. They are employed in applications requiring high starting torques or where large pulsating loads are encountered. They are seldom employed for speed variation by field control, because weakening the shunt field would produce relatively more of the series motor characteristics.

Wherever line voltages fluctuate suddenly or considerably, compound motors are useful. Such conditions are encountered in mine equipment. The motors are also useful for elevators, pumps, compressors, printing equipment and other machinery where the load fluctuates suddenly or periodically and where constant speed is not essential.

Usually the series and shunt fields are wound so that their flux densities are additive to produce a combined stronger field. This type of winding is called cumulatively wound. If, however, the two fields are wound in opposite directions to oppose each other, i.e., the series field flux decreases the flux on the shunt field, the motor is differentially wound. These motors are seldom used because of the possibility of unstable starting conditions. Under certain conditions, they may fail to start or may start in the wrong direction until the field builds up to cause reversal.

As with the other types of motors, compound motors may operate in parallel connections of two or more motors if the speed regulation of each is identical so that the load may be divided. If the motor characteristics do not match, insertion of a resistance in the armature circuit is not effective. Changes in the current values or flux densities do not affect the motors equally over their operating ranges, making it difficult to balance the motors. A separate exciter, however, may be employed to control the series field, providing the desired field strength over the operating range.

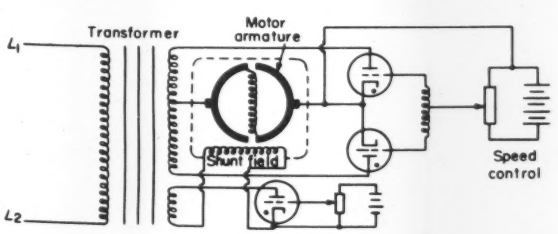
Reversing a compound motor is effected as in the other motors by reversing either the field or armature. Plug reversal or stopping is obtained in a manner similar to that for shunt motors by placing resistors in the circuits. Dynamic braking is also employed for cushioned deceleration by disconnecting the armature from its series field and inserting a resistance across the armature, leaving the shunt field energized. Reversing the series field connections and including it in the resistance circuit with the armature further increases the decelerating action.

Table 24—Speed Regulation of Compound-Wound Motors*

Motor Rating (hp)	Full-Load Speed (rpm)	Speed Regulation (max. %)	No-Load Speed (max. rpm)
1/20-1/8	1725	30	2240
	1140	35	1890
1/6-1/3	1725	25	2160
	1140	30	1480
1/2-3/4	1725	22	2100
1/2	1140	25	1430

* Based on NEMA Standards. Maximum speed regulation values are standardized by NEMA. It is the percentage change in speed from no-load to full-load conditions with respect to full-load speed at rated voltage.

Fig. 89— Electronic adjustable speed drive employing single-phase power and a shunt drive motor



—Courtesy, Westinghouse Electric Corp.

Fig. 90—Speed-torque characteristics for an electronic adjustable speed drive showing curves for both field and armature voltage control. The former varies the speed from 100 to 200 per cent of rated and produces constant horsepower. The latter varies the speed below rated and produces constant torque as shown by the dash line

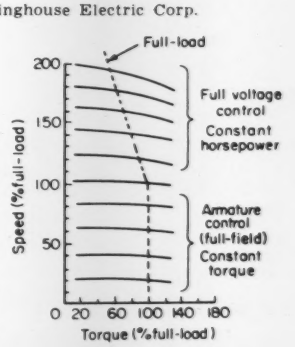
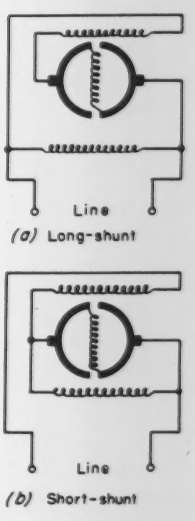


Fig. 91—Long-shunt and short-shunt connected compound-wound motors. The latter approaches more the characteristics of a series motor than the former



General Application Factors .....

AMOUNT OF WORK that a motor can perform is limited by its temperature. This, of course, does not apply to torque motors which are designed for stalled conditions and will not overheat. Normally, the ability of a motor to perform under heavy overload conditions is a useful feature, allowing the use of smaller motors for high peak loads. These loads, however, must be of sufficiently short duration to avoid overheating. Continuous-duty motors are usually capable of driving loads 115 per cent of rated horsepower continuously without damage from overheating (1.15 service factor).

In addition to determining the average continuous horsepower requirements of a machine, the designer should ascertain the starting and peak torques required. From this information, the motor to fit the drive may be selected. Insofar as possible, he should select the motor to operate at the maximum power (without overheating) it is capable of handling, whether the duty cycle involves continuous operation, intermittent operation, frequent starting, or reversing duty. In so doing, he selects the most economical drive because the motor will be operating near peak efficiency and power factor.

Also, motor speed and speed regulation over the load range should be checked, balancing costs and other motor characteristics against the drive requirements. It should be borne in mind that more constant speed (good regulation) is obtained at the expense of available torque. Also current peaks are somewhat higher. Since horsepower is proportional to speed and torque, either horsepower, P, or torque, T in lb-ft, is determined when the other two variables are known. If speed is expressed as S, in rpm, this relationship is

$$P = \frac{ST}{5250} \text{ horsepower}$$

Load Requirements: In determining the drive requirements of a machine there are many methods, any one of which may be satisfactory. Wherever possible, load tests should be conducted on the machine itself, duplicating conditions under which the machine will normally operate. With this method the watts input can be carefully measured and the power requirements determined from the efficiency curve of the drive motor being used. Then, knowing the watts input, w, and the motor efficiency, e, the horsepower, P, required for continuous loading is

$$P = \frac{we}{746}$$

Another method involves comparisons with other machines that have been designed to do similar work. The danger of this method is that the designer, knowing the variables and inaccuracies of the method, is apt to select a motor that is too large. This unnecessary extravagance should be avoided wherever possible. If the motor is selected in the design stages, precluding load testing of the machine, accurate calculations of the loads may be performed. This requires information not only on the power requirements of the ultimate operations but also on the efficiency of every intermediate component or mechanism that may have a significant influence on the drive motor.

Duty Cycle: Usually, on machines in which the motor is running continuously during operation, the load demand on the motor varies during the operating cycle. When these loads can be determined and charted as repeating cycles having the same load characteristics, the root-mean-square horsepower method of determining motor size is useful. In effect, this method incorporates the increased rating possible from intermittent-duty operation between peak demand and minimum power requirements.

This method of horsepower determination involves the square root of the quotient obtained from the sum of each horsepower requirement squared multiplied by each period of time, respectively, and divided by the total cycle time, allowing only ½ the idle time for enclosed motors or 1/3 the idle time for open motors in the time cycle. To illustrate this method, it may be assumed that an enclosed motor is desired for a machine which has a duty cycle requiring 2, 3, 4, and 0 horsepower for 20, 40, 10, and 60 seconds, respectively, the last being an idle period. The rms horsepower required by the machine would be

$$P_{rms} = \sqrt{\frac{20(2)^2 + 40(3)^2 + 10(4)^2 + 60(0)^2}{20 + 40 + 10 + 1/2(60)}} = 2.6 \text{ hp}$$

Inasmuch as 2.6 exceeds the normal 15 or 20 per cent overload rating of a 2-horsepower motor, a 3-horsepower motor is required. Any general-purpose 3-horsepower motor will develop sufficient power to carry the intermittent 4-horsepower load.

In applying this rms horsepower method it is always necessary to determine if the motor will develop sufficient torque to carry the peak load and whether the resulting speed reduction during this period would be objectionable. Peak torques that a motor is capable of developing should preferably be at least 25 per cent higher than the load demand to allow for possibility of low voltage, unanticipated loading, etc. Also, the motor should have sufficient starting torque for the application.

Frequently, the choice of the proper type of motor may allow the application of a smaller horsepower size. For instance, rms horsepower calculations for a machine may require 10 horsepower. However, a

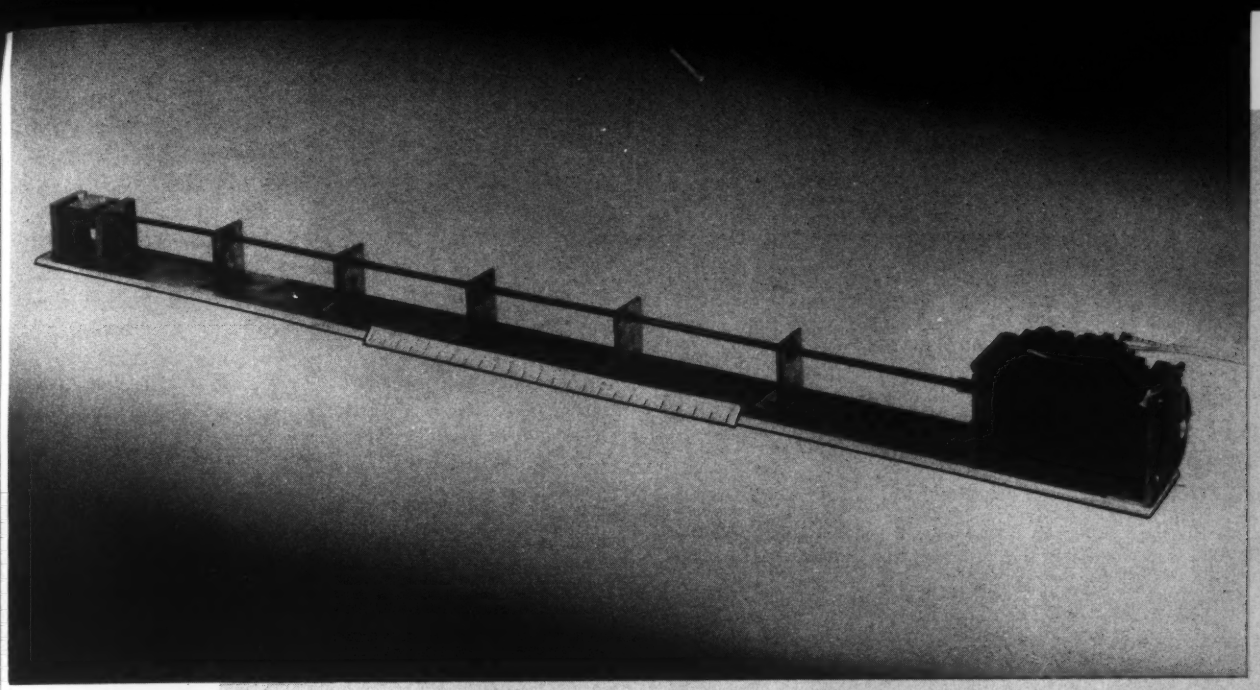


Fig. 92—Rapid reversing motor capable of reversing at an unlimited rate. During reversal, energy to stop rotor is stored in a spring and returned to the rotor during acceleration in the reverse direction

—Courtesy, National Bureau of Standards

peak load of short duration of 200 per cent full-load torque would be beyond dependable operation of, say, a 10-horsepower, Design *B*, general-purpose squirrel-cage polyphase motor. Although this motor will deliver an expected 200 per cent maximum torque, using a factor of 75 per cent would provide only 150 per cent, indicating use of a 15-horsepower motor. Instead, however, a Design *A*, 10-horsepower motor, having a breakdown torque of 270 per cent, could be applied safely without fear of stalling ($0.75 \times 270 = 202\%$). Use of the Design *A* motor, in this application although starting current is 10 per cent higher, would result in a smaller motor at a lower cost than if a Design *B* motor were employed.

In applying a Design *A* motor, the designer should ascertain if its starting torque is adequate. Although starting current is higher, torque is lower than for Design *B* motor.

Stopping and Reversals: When frequent stopping (plugging, dynamic or regenerative braking) or reversing are encountered in a duty cycle, calculations become involved. Heating may be excessive due to the frequent change in speed of the motor and its connected load. When the inertia of the connected load and that of the drive motor are known the maximum number of reversals per minute of a given motor on a specific application can be calculated. The limiting factor, of course, is the heating of the motor. To determine the inertia load connected to a motor, it is necessary to translate the speed of the connected load to that of the motor. The Wr^2 of the load can be converted to an equivalent value at the motor shaft by multiplying by the square of the speed ratio. Expressed as a formula, where S_d is the speed of the driven member and S_m is the speed of the motor, the equivalent Wr^2 of the connected rotating parts becomes

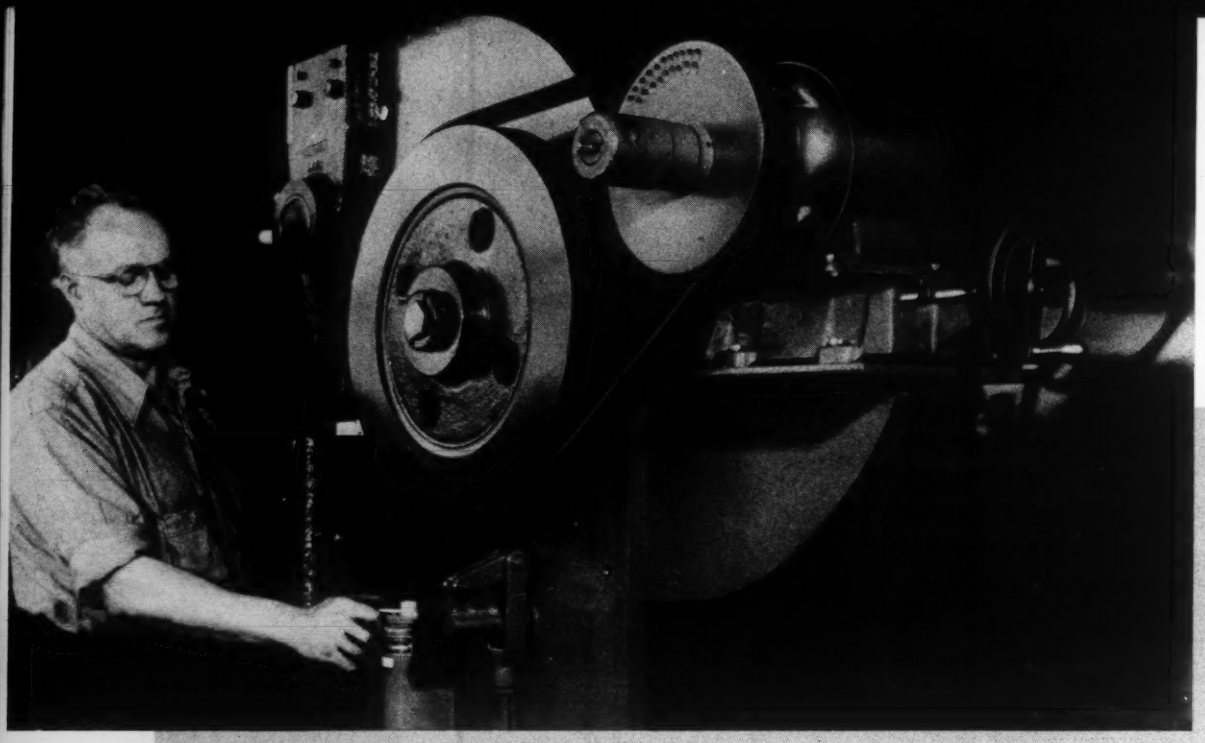
$$(Wr^2)_e = Wr^2 \left(\frac{S_d}{S_m} \right)^2$$

As a general yardstick, one plug reversal of a motor is regarded as equal to four motor starts, based on motor heating. For this reason, although many reversal operations are performing successfully with as many as 10 to 15 per minute with connected loads, it is recommended that the engineering department of the motor manufacturer be consulted for recommendations when reversing or frequent starting is involved.

With no connected load, many motors cannot reverse more than 2 to 5 times a minute without overheating. When connected parts are also reversed by the motor, the duty becomes much more severe depending on the frequency of reversal, speed of the drive, and the inertia of the connect load.

Sausage type motors may be employed where reduced rotor Wr^2 would be advantageous.

For motors having the same horsepower and electrical characteristics, the cylindrical surface area of the rotor remains constant ($DL = C$). In other words, if the rotor length is increased 10 per cent, the diameter is decreased by a like amount. Inasmuch as the moment of inertia of a motor rotor is a function of the product of the diameter to the fourth power and the length, the moment of inertia then becomes proportional to the third power of the diameter ($Wr^2 \approx D^3$). In other words, a reduction of 20 per cent in diameter would result in almost 50 per cent less Wr^2, and a reduction of 50 per cent in diameter would mean a reduction of 87.5 per cent in Wr^2.



—Courtesy, Westinghouse Electric Corp.

Fig. 93—Flywell driving a press and shear. Variable-speed pulley provides a 2 to 1 speed range

In starting an ac motor and its connected load, the heat generated by the rotor is equal to the work performed. This heating is a function of the Wr^2 (of motor and equivalent connected load), the square of the motor speed, the ratio of the stator resistance to rotor resistance, difference in motor slip (from initial to final), and a factor depending on the number of poles in the motor. A discussion of these relations and their values has been presented by R. J. Owen and J. J. Kirkish in "Selecting Special Motors, Part V—Frequent Starting and Reversing Motors," MACHINE DESIGN, May 1941.

In considering the rotor heating (I^2R loss) during acceleration of a motor (stator or field losses being considered negligible), a mechanical clutch analogy shows how this heat equals the energy value of the work in accelerating a motor. Considering the rotating field of the motor as the driving element and the rotor as the driven element of a clutch, the equality becomes readily apparent. At the instant of clutch engagement or motor energization, the slip is 100 per cent and all the energy is dissipated as heat. As acceleration progresses, speed of the driven elements increases to the point of full engagement or no slip. Whether the torque characteristics are a straight line with respect to speed or increase at a varying rate, the average over the accelerating period is the same. Thus the heat generated is equal to the work done. If the motor has a connected inertia load, the equivalent Wr^2 of the connected load is added to the rotor inertia in determining heating. The heat capacity of the motor for infrequent starting or the heat dissipating ability for frequent starts determines the ability of a motor to perform under such conditions.

Plug stopping is much more severe duty than starting because of the increased current flow resulting from the induced current flux adding instead of bucking to reduce the effective resistance. This loss becomes heat. Regarding a plug reversal as developing four times as much heat as a motor start, a plug stop therefore results in three times the heating of a start.

In one design of small motor for rapid reversal, the rotor consists of a solid piece of steel, without bars or rings, which avoids strains due to rapid temperature changes caused by sudden rush of current. Between the rotor and stator coils is an air blast from a separate blower. The rotor, in some cases, may turn blue from heat of reversing without harming the windings.

To relieve a motor of some of the heat burden of starting and stopping loads, clutches and brakes (built-in or connected) have been employed to advantage in many applications. Insofar as inertia is concerned, these units add to the load but allow for performing the operations mechanically instead of electrically. An unusual experimental motor for rapid reversing is illustrated in *Fig.* 92. In this novel motor, the energy for reversing is not dissipated as heat. The energy required to decelerate the motor is stored in a torsion spring and returned to the motor during acceleration in the opposite direction. In this way, regardless of the number of reversals, no energy is lost during reversal, except negligible friction in the clutch and spring.

Developed at the National Bureau of Standards for use in high-speed reversals of magnetic tape in a computer memory device, the motor, *Fig.* 92, is a low-inertia motor operating at 3200 rpm. Because it operates as a single-phase induction motor, it will run in the direction in which it is accelerated, either forward or reverse. One end of the torsion spring is connected

to the motor rotor and the other to a two-way clutch element. The driven clutch element is restrained from turning so that engagement of the reversing clutch locks the spring. This winds up the spring until all the inertia of the motor is stored in the spring whereupon the spring returns this energy to the rotor by accelerating it in the opposite direction, disengaging the clutch.

Problem of applying a torsion spring of this type is the length required to provide sufficient flexibility for reversing the motor without undue shock. This particular motor is 1/75-horsepower and the spring is 3/16-inch in diameter, 31 inches long, stopping the motor within 20 degrees of rotation. Complete reversal is effected in about 3 milliseconds.

To electrically accelerate a motor, the time required to attain a given speed may be determined from the equation

$$t = \frac{Wr^2 S}{308 T_e}$$

where t is the time in seconds, S is speed in rpm, and T_e is equivalent accelerating torque in lb-ft. Inasmuch as time is proportional to the reciprocal of the torque, the equivalent torque in this equation would be equal to the reciprocal of the average reciprocal taken from a convenient number of accelerating torque values for equal intervals on the speed torque curve of the motor.

Cooling: As mentioned previously, motor performance on severe duty-cycle applications is limited by motor heating. In many applications, additional ventilation—resulting in lower motor temperatures by increasing the dissipation of the heat—is obtained by running the motor at no-load conditions during the idle period. The effects of the additional cooling obtained by this method is reflected in the rms horsepower formula. Where this cooling is insufficient forced cooling from an external blower may keep temperatures within safe values.

When an enclosed, forced-ventilated motor is employed, the amount of air required to maintain the same temperature as an open motor with normal ventilation is usually estimated at 150 cubic feet per minute per kilowatt loss. This volume of air V (cfm) in terms of watts w and motor efficiency e is

$$V = \frac{150w(100 - e)}{100{,}000} \text{ cfm}$$

Expressed in terms of current input I (amp), voltage V, and power factor P the volume of air required becomes

$$V = K \frac{150\,IVP(100 - e)}{100{,}000} \text{ cfm}$$

where K is a factor depending on the power supply. For single-phase motors, $K = 1$; for 2-phase, 4-wire motors, $K = 2$; for 2-phase, 3-wire motors, $K = 1.41$; and for 3-phase motors, $K = 1.73$. Air pressure required at the motor varies with the motor size and construction but averages 1 to 2-inch water gage. To this is added the resistance in the piping to determine the blower pressure.

Flywheel Loads: In applications involving high peak loads for short periods in the duty cycle, flywheels may be utilized to advantage. Typical of machines where flywheels are employed are punch presses and shears, *Fig.* 93. When the flywheel is of sufficient capacity and the motor is properly selected, current peaks in the power input are minimized, the current draw being relatively constant. An application is designed so that the flywheel gives up energy during the peak demand. This necessitates, of course, that the speed be reduced, speed being restored by the motor between peak demands.

The motor must be selected so that it will not try to maintain constant speed. Instead the ideal motor would only supply constant torque, regardless of decreased speed. Motors designed for this purpose are often called torque motors, being high-slip Design *D* units (7-11 per cent slip). They bring the flywheel back to speed and slip sufficiently to allow the flywheel to dissipate energy. The duty cycle of the motor, in other words, equals the amount of torque required to get the flywheel back to speed within the cycle period. If the duty cycle is lengthened a smaller motor could be employed, producing the same peak load because the motor drives the flywheel, not the load.

To illustrate the application of a motor to a flywheel load, motor speed and torque are plotted against time for a typical load in *Fig.* 94. After the

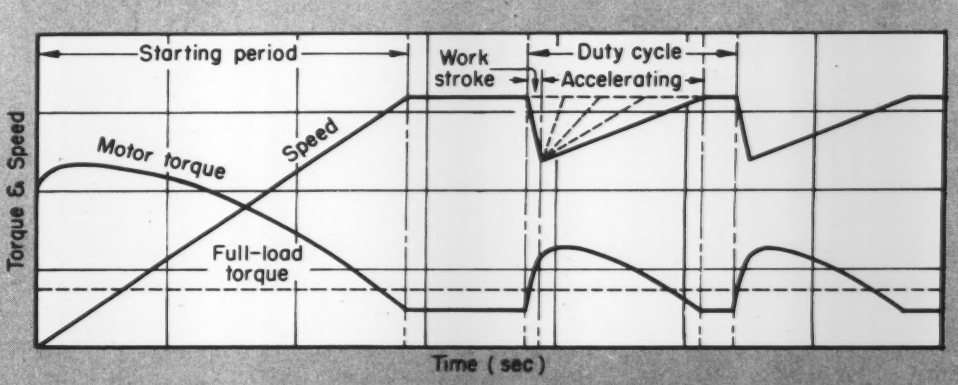


Fig. 94—Speed and torque curves for a flywheel duty cycle. The motor is selected to restore speed over as long a period as possible within cycle

motor has accelerated the flywheel to its full speed, the duty cycle consists of work-stroke, reacceleration and full-speed periods which repeat consecutively and uniformly. Stored energy in the flywheel is selected so that it can perform the work stroke in the time required by losing speed as indicated in *Fig.* 94. The motor then restores speed to the flywheel, having sufficient torque to regain speed before the next work stroke. Dotted lines in the speed curve are for alternative motors which would restore speed more quickly. The best motor, however, is the one which restores the speed over the longest period possible within the duty cycle, allowing a minimum time of full speed before the next work stroke. Otherwise the application would be overmotored and the flywheel would not be employed for its maximum utilization. Also, the motor would be idling a greater period and the current draw would fluctuate more markedly.

In selecting a motor for a flywheel, it is necessary to know the amount of work to be performed by the flywheel as well as the initial and final speeds of the flywheel during the work stroke. Then, if the work stroke is a small part of the duty cycle, the horsepower, P, required becomes

$$P = Wr^2 \frac{S_1^2 - S_2^2}{3.23(10)^6 t}$$

where Wr^2 is the moment of inertia of the flywheel in lb-ft^2, S_1 and S_2 are the initial and final speeds, respectively, in rpm, and t is the duty-cycle time in seconds during which the flywheel must recover its speed. If the motor inertia is to be included, calculations may be made separately or combined by using equivalent inertias. Also, the torque supplied by the motor during the power stroke aids the flywheel and may be deducted from calculations for flywheel work.

Generally, in flywheel applications, the work stroke is less than 15 per cent of the duty cycle. As the stroke time increases, the advantages of a flywheel become less. Use of a flywheel and matched torque motor usually results in a 50 per cent power saving compared to using a general-purpose motor.

These general application factors indicate the considerations involved in matching a motor to its drive requirements. In any specific machine there may be special factors not covered by this discussion. The general approach, however, would be much the same, picking the particular motor to best fit the needs. In critical applications, the exact data on the characteristics of the motor being selected should be obtained and matched against the load requirements. In this respect, as mentioned previously, electrical features may be altered but this usually involves sacrificing others. For this reason it is necessary to review all characteristics carefully to determine the best compromise.

The helpful co-operation of the National Electrical Manufacturers Association (NEMA) in the preparation of this article is greatly appreciated. Also, without the help of many machinery manufacturers and motor builders, this presentation could not have been possible. The motor manufacturers contributing to this article are representative of the industry and particular acknowledgement is made to the following companies for their assistance.

Alliance Manufacturing Co., Alliance, Ohio
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Allis, Louis, Co., Milwaukee, Wis.
Baldor Electric Co., St. Louis 10, Mo.
Barber-Colman Co., Rockford, Ill.
Bodine Electric Co., Chicago 12, Ill.
Brown-Brockmeyer Co., Dayton 1, Ohio
Century Electric Co., St. Louis 3, Mo.
Crocker-Wheeler Division, Elliott Co., Jeannette, Pa.
Delco Products Div., General Motors Corp., Dayton 1, Ohio
Diehl Mfg. Co., Finderne Plant, Somerville, N. J.
Doerr Electric Corp., (Electro Machines Inc.) Cedarburg, Wis.
Electric Indicator Co., Stamford, Conn.
Electric Motor Corp. Div., Howard Industries, Racine, Wis.
Electric Specialty Co., Stamford, Conn.
Electro Dynamic Div., Electric Boat Co., Bayonne, N. J.
Emerson Electric Mfg. Co., St. Louis 21, Mo.
Fairbanks, Morse & Co., Chicago 5, Ill.
Fasco Industries Inc., Rochester 2, N. Y.
Forbes & Myers, Worcester 8, Mass.
General Electric Co., Schenectady 5, N. Y.
General Industries Co., Elyria, Ohio
Heinze Electric Co., Lowell, Mass.
Holtzer-Cabot Division, National Pneumatic Co. Inc., Boston, Mass.
Hoover Co., Kingston-Conley Div., North Plainfield, N. J.
Howell Electric Motors Co., Howell, Mich.
Jack & Heintz Inc., Cleveland, Ohio
Janette Mfg. Co., Chicago 6, Ill.
Lamb Electric Co., Kent, Ohio
Lear Inc., Grand Rapids, Mich.
Leece-Neville Co., Cleveland, Ohio
Leland Electric Co., Dayton, Ohio
Lima Electric Motor Co., Lima, Ohio
Marathon Electric Manufacturing Corp., Wausau, Wis.
Marco Industries Inc., Depew, N. Y.
Master Electric Co., Dayton 1, Ohio
Ohio Electric Mfg. Co., Cleveland 27, Ohio
Oster, John, Mfg. Co., Racine, Wis.
Peerless Electric Co., Warren, Ohio
Pesco Products Div., Borg-Warner Corp., Bedford, Ohio
Rae Motor Corp., 2009 Kewaunee St., Racine, Wis.
Redmond Co. Inc., Owosso, Mich.
Reliance Electric & Engineering Co., Cleveland 10, Ohio
Reuland Electric Co., Alhambra, Calif.
Reynolds Electric Co., River Grove, Ill.
Robbins & Myers Inc., Springfield 99, Ohio
Scruggs, Loyd, Co., St. Louis 1, Mo.
Signal Electric Mfg. Co., Menominee, Mich.
Smith, A. O., Corp., Dayton 4, Ohio
Star-Kimble Motor Div., Miehle Printing Press & Mfg. Co., Bloomfield, N. J.
Sterling Electric Motors Inc., Los Angeles 22, Calif.
U. S. Electric Motors Inc., Los Angeles 54, Calif.
Universal Electric Corp., Owosso, Mich.
Valley Electric Corp., St. Louis 8, Mo.
Victor Electric Products Inc., Cincinnati, Ohio
Wagner Electric Corp., St. Louis 14, Mo.
Wesche, B. A., Electric Co., Cincinnati, Ohio
Westinghouse Electric Corp., Pittsburgh 30, Pa.
Wincharger Corp., Sioux City 6, Iowa

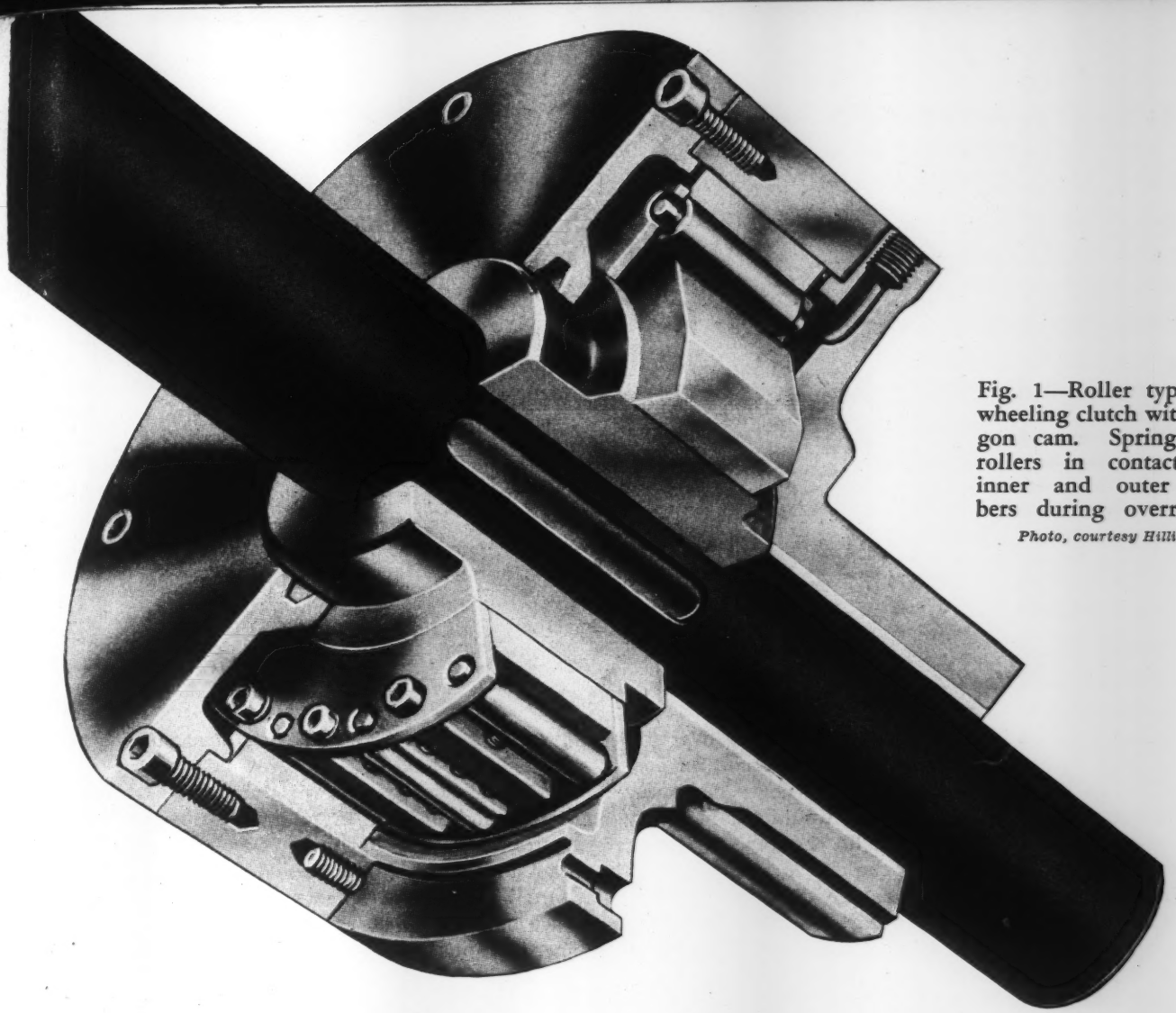


Fig. 1—Roller type freewheeling clutch with polygon cam. Springs keep rollers in contact with inner and outer members during overrunning

Photo, courtesy Hilliard Corp.

Freewheeling Clutches

Design and application factors for roller and sprag one-way units

By Dietrich W. Botstiber
President
Technical Development Co.
Philadelphia, Pa.

and

Leo Kingston
Staff Stress Engineer
Piasecki Helicopter Corp.
Morton, Pa.

FREEWHEELING units, also known as one-way clutches or overrunning clutches, are used in many types of machinery. Recent accelerated development of automatic transmissions for automotive vehicles, and mechanical drives for rotary wing aircraft and certain types of multiengine fixed-wing aircraft, have given a major boost to the development of this machine element. This article will discuss only those types of freewheeling units that are used for power transmission where space and weight are limited, and where optimum functional behavior of the unit is required.

Usually a freewheeling clutch is defined as a form of connection between rotating units that transmits full power in one direction of rotation and none in the other. More generalized, it is a unit which transmits greater torque in one direction than in the other. In the majority of designs, the greater or driving

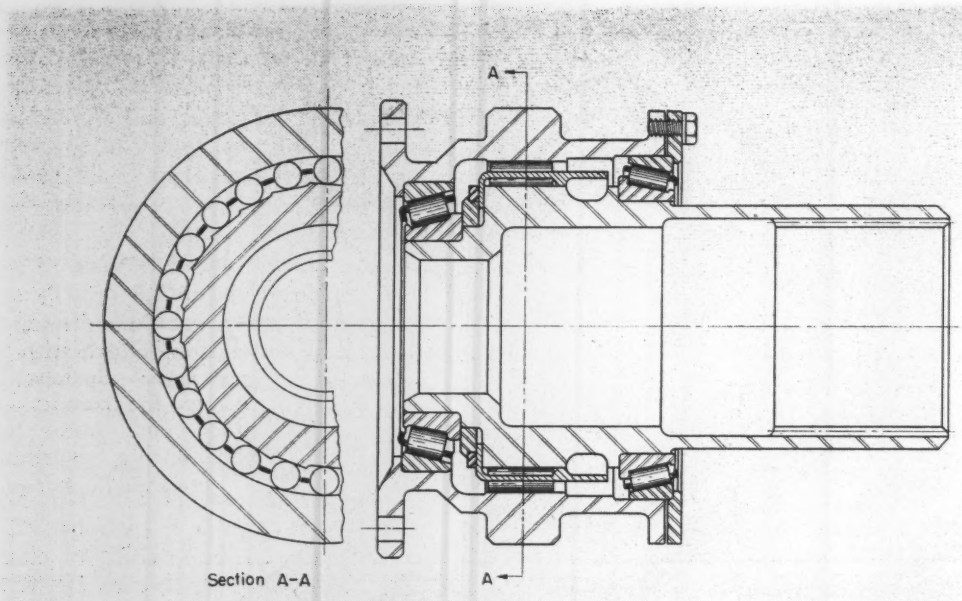


Fig. 2 — Left — Typical light-weight freewheeling clutch with saw-tooth cam for accommodating a maximum number of rollers

Fig. 3—Right—Geo try of roller cl

torque is held as high as possible, while the overrunning or freewheeling torque is held as small as possible. The freewheeling torque may never disappear completely, for if it did, the unit would not be ready to re-engage when the speed of the input member tends to exceed the speed of the driven member.

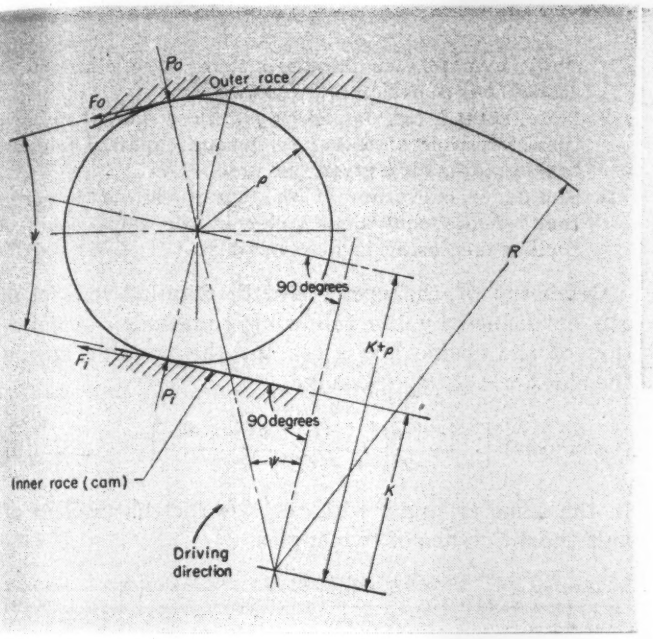
In most freewheeling drives the direction of rotation is the same in all operating conditions, and only the relative speeds of driving and driven members control the overrunning or driving effect. On an electric generator coupled to two prime movers by freewheeling clutches, one prime mover may be running while the other one is stopped. In this case, one clutch is driving and the other is overrunning with its input member standing still. In an automotive torque converter drive, one member of the hydrodynamic unit may be coupled to the shaft by a freewheeling unit, and under certain operating conditions it will then idle along with the freewheeling unit overrunning. Helicopters contain freewheeling units which permit the rotors to turn under the influence of external aerodynamic forces when the engine is throttled and the ship is gliding in a manner comparable to a fixed-wing airplane.

Where the operating conditions of a drive require careful limitation of the stresses in the drive elements, an essential requirement is to reduce or eliminate shock loads and vibrations. Hence, it is of utmost importance to reduce lost motion in the freewheeling unit to a minimum. In the transition from overrunning to driving, the driving member speed should not be allowed to exceed the speed of the driven components. Otherwise, stored kinetic energy can produce dangerous shock loads in the drive system. The amount of lost motion in the driving direction of a simple ratchet type unit depends on the tooth spacing. In the sprag and roller type clutch, or in any other stepless unit, an almost immediate torque build-up takes place and the lost motion is governed largely by elastic deformation of the clutch parts under load.

Possible designs for producing freewheeling effect are almost infinite in number. However, as the requirements for optimum functional characteristics and manufacturing practicability are considered, the number of suitable designs narrows to a few. Only two major systems are currently used in a large number of applications for high power ratings and high speeds.

Roller Clutch: Until a few years ago, the most frequently used freewheeling clutch was based on the wedging roller principle, *Fig.* 1. The inner member, frequently called the cam, is polygon-shaped. Its flat surfaces provide the tapered spaces for the rollers. Different design approaches shape this part either like a saw-toothed wheel, *Fig.* 2, or just like a symmetrical polygon, but in either case the effect is the same. If the cam lobes are symmetrical in contour, a retainer or cage for the rollers must be provided to limit their motion in the overrunning position and to keep them equally spaced. In overrunning position, the rollers must always contact both inner and outer members, so that in case of torque reversal, all rollers respond simultaneously by moving into driving position toward the smaller end of the tapered space. If the clutch parts were completely inelastic and no sliding action existed, the smallest deviation from perfect uniformity of engagement would put all the load on one roller alone. However, the effect of inaccuracies is reduced by deflections of the material and the tendency of this clutch to increase the wedging angle with increasing load, as shown in the following analysis.

In *Fig.* 3, rotation of the inner race in the direction of the arrow marked "driving" tends to wedge the roller between the outer race and the flat portion of the cam, and thereby causes transmittal of torque. From *Fig.* 3,



$$\psi = \cos^{-1} \frac{K + \rho}{R - \rho} \quad \ldots\ldots (1)$$

Equilibrium conditions for the roller are readily established preparatory to relating P_o and F_o. For the sum of the moments equated to zero,

$$F_o\rho - F_i\rho = 0$$

$$F_i = F_o$$

Similarly, for vertical forces

$$(P_o - P_i) \cos \frac{\psi}{2} + (F_o - F_i) \sin \frac{\psi}{2} = 0$$

$$P_o = P_i$$

Finally, for horizontal forces

$$(P_o - P_i) \sin \frac{\psi}{2} - (F_o + F_i) \cos \frac{\psi}{2} = 0$$

Therefore,

$$P_o = F_o \cot \frac{\psi}{2} \quad \ldots\ldots (2)$$

During positive driving, the torque, Q, on the outer race is

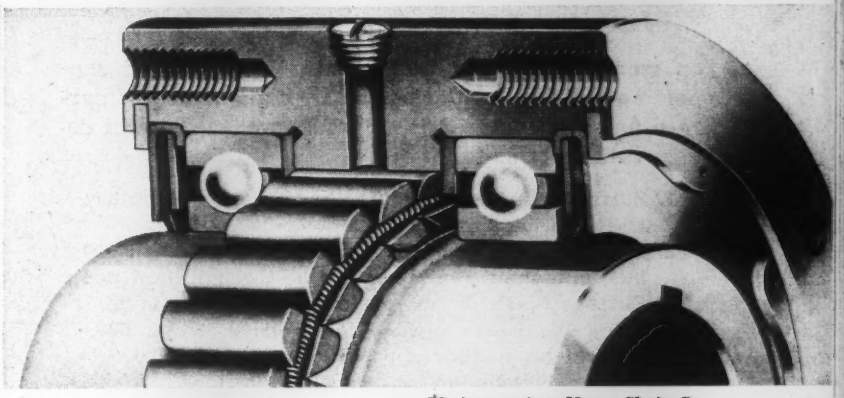
$$Q = F_o R\, n \quad \ldots\ldots (3)$$

where n = number of rollers. With p = force per unit of roller length,

$$p = \frac{P_o}{l} = \frac{F_o}{l} \cot \frac{\psi}{2} \quad \ldots\ldots (4)$$

The limit of the torque capacity is governed by the surface compressive stress of roller and cam. It is determined by the Hertz equation:

$$s_c = 0.591 \sqrt{\frac{pE}{2\rho}} \quad \ldots\ldots (5)$$



Photo, courtesy Morse Chain Co.

Fig. 4—Cutaway view of typical sprag clutch. Garter springs maintain light pressure of sprags against races during overrunning

where s_c = surface compressive stress and E = modulus of elasticity.

Expressing the allowable tangential force F_o as a function of Hertz stress, by substitution of Equation 5 in Equation 4, gives

$$F_o = \frac{2\rho}{E}\, l \left(\frac{s_c}{0.591} \right)^2 \tan \frac{\psi}{2} \quad \ldots\ldots (6)$$

By substitution of Equation 6 into Equation 3 and with E = 31,000,000 psi, the torque capacity is

$$Q = 1.91 \times 10^{-7}\, S_c{}^2 R n l \rho \tan \frac{\psi}{2} \quad \ldots\ldots (7)$$

In practical design, the limits of these terms must be checked for all operating conditions. Factors l and n remain constant, but R, ρ and ψ change under the influence of applied load. Limiting conditions are set by several considerations.

The tangent of the initial angle $\psi/2$ must be less than the coefficient of sliding friction. Otherwise, engagement will not take place. Once the clutch has started to engage, the angle ψ will increase due to increase of R (expansion of the outer race) and due to decrease of ρ and K (compression of the roller and cam). Friction then changes from sliding to static, raising the limit for tan $\psi/2$ to the coefficient of static friction. Also, the high compression at the surface will break the film of lubricant, further increasing the static friction.

The rigidity of the parts, particularly cam and outer race, must be adequate to prevent $\psi/2$ from increasing above the allowable limit. In actual design, the procedure is to calculate the expansion of the outer race and compression of inner race and cam, under load, and then to recalculate the new angle, ψ'. By modification of Equation 1,

$$\psi' = \cos^{-1} \left[\frac{(K - \Delta K) + (\rho - \Delta\rho)}{(R + \Delta R) - (\rho - \Delta\rho)} \right] \quad \ldots\ldots (8)$$

where ΔK, $\Delta\rho$ and ΔR are the dimensional changes under load. This equation is best solved by trial and error, since $\Delta\rho$, ΔK and ΔR are functions of Q and ψ'.

The permissible limit for surface stress s_c depends

on metallurgical conditions of the surfaces and supporting sections of the parts. A high degree of surface finish is required to minimize wear. Typical design values are as follows:

1. Surface hardness of outer race, cam and roller: 60 Rockwell C minimum
2. Depth of hard case for cam and outer race: 0.090 inch minimum. Rollers should be through hardened
3. Surface finish: 5 rms desired, 10 rms maximum
4. Allowable Hertz surface compressive stress: 600,000 psi at maximum possible overload; 350,000 is a desired maximum for continuous load
5. Initial engagement angle ψ: 6 deg maximum
6. Final engagement angle ψ' (under full load): 9 deg maximum
7. Length-to-diameter ratio of roller: from 2 to 3

Since designs of outer race and cam are governed by rigidity requirements, analysis for tensile and compressive stresses, respectively, is not required. Analysis for surface compressive stress is sufficient.

Sprag Clutch: Illustrated in *Fig.* 4, the sprag clutch is composed of circular inner and outer races and irregularly shaped wedging elements, or sprags. Operation of the clutch can be deduced from *Fig.* 5. As the outer race rotates in the driving direction, each clutch sprag tends to rotate clockwise with respect to itself. Because of the offset centers of curvature, wedging results and torque is transmitted.

Popularity of sprag clutches has grown in recent years for several reasons:

1. Since sprags, the locking elements, are commercially available as standard items, the clutch is economical to design and manufacture
2. More sprags can be employed in a given space than can rollers; therefore, torque capacity tends to be greater for a given size unit
3. Radius of curvature of the sprag can be larger than of the equivalent roller in the same space, further increasing torque capacity.

Geometry of the sprag clutch, detailed in *Fig.* 5, can be defined by the following equations. Application of the cosine law gives for the triangle having the sides, $r + \rho$, $R - \rho$, and d,

$$\phi = \cos^{-1}\left[\frac{(r+\rho)^2 + (R-\rho)^2 - d^2}{2(r+\rho)(R-\rho)}\right] \quad \ldots\ldots (9)$$

In the same triangle, with the law for the tangent of half the difference of two angles,

$$\frac{\omega - \gamma}{2} = \tan^{-1}\left[\frac{R-r}{R+r}\tan\left(90 - \frac{\phi}{2}\right)\right] \quad \ldots\ldots (10)$$

Also from *Fig.* 5,

$$\omega = 180 - (\phi + \gamma) \quad \ldots\ldots (11)$$

and

$$\theta = 180 - \omega = \phi + \gamma \quad \ldots\ldots (12)$$

or if θ is known,

$$\gamma = \sin^{-1}\left(\frac{r}{R}\sin\theta\right) \quad \ldots\ldots (13)$$

Forces under equilibrium conditions can be related

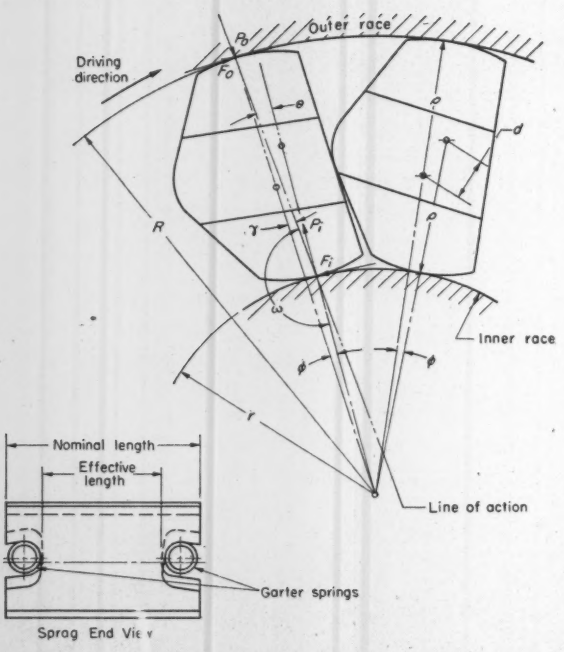


Fig. 5—Left—Geometry of sprag clutch

Fig. 6—Right—Packard automatic transmission with freewheeling unit for holding converter reactor against rotation during acceleration

by several simple equations. Since the resultant of F_i and P_i must be on the line of action,

$$P_i = F_i \cot \theta \quad (14)$$

$$P_o = F_o \cot \gamma \quad (15)$$

From equated moments,

$$F_o = F_i \frac{r}{R} \quad (16)$$

For small angles, as characteristic for this application, sin θ is approximately equal to tan θ. Therefore,

$$P_o \approx P_i \quad (17)$$

Torque transmitted by the clutch is simply

$$Q = F_i r n \quad (18)$$

where n = number of sprags. From Equation 14, the pressure per unit of effective length l is

$$p = \frac{F_i}{l \tan \theta} \quad (19)$$

The surface compressive stress by the Hertz equation for two cylindrical bodies is

$$s_c = 0.591 \sqrt{pE \frac{r + \rho}{2r\rho}} \quad (20)$$

From Equations 19 and 20,

$$F_i = \frac{2r\rho l}{E(r + \rho)} \left(\frac{s_c}{0.591} \right)^2 \tan \theta \quad (21)$$

Finally, by substitution of Equation 21 in Equation 18,

$$Q = 1.91 \times 10^{-7} \frac{nl\rho r^2 s_c^2 \tan \theta}{r + \rho} \quad (22)$$

The limits for the various factors in a practical design are as follows:

1. Surface hardness, case depth, surface finish and limits for surface compressive stress: same as for roller clutch
2. Initial angle θ, corresponding to $\psi/2$ on the roller clutch: 3 to 4 deg maximum

Comparison: Several significant points mark the functional differences in the roller and sprag clutches.

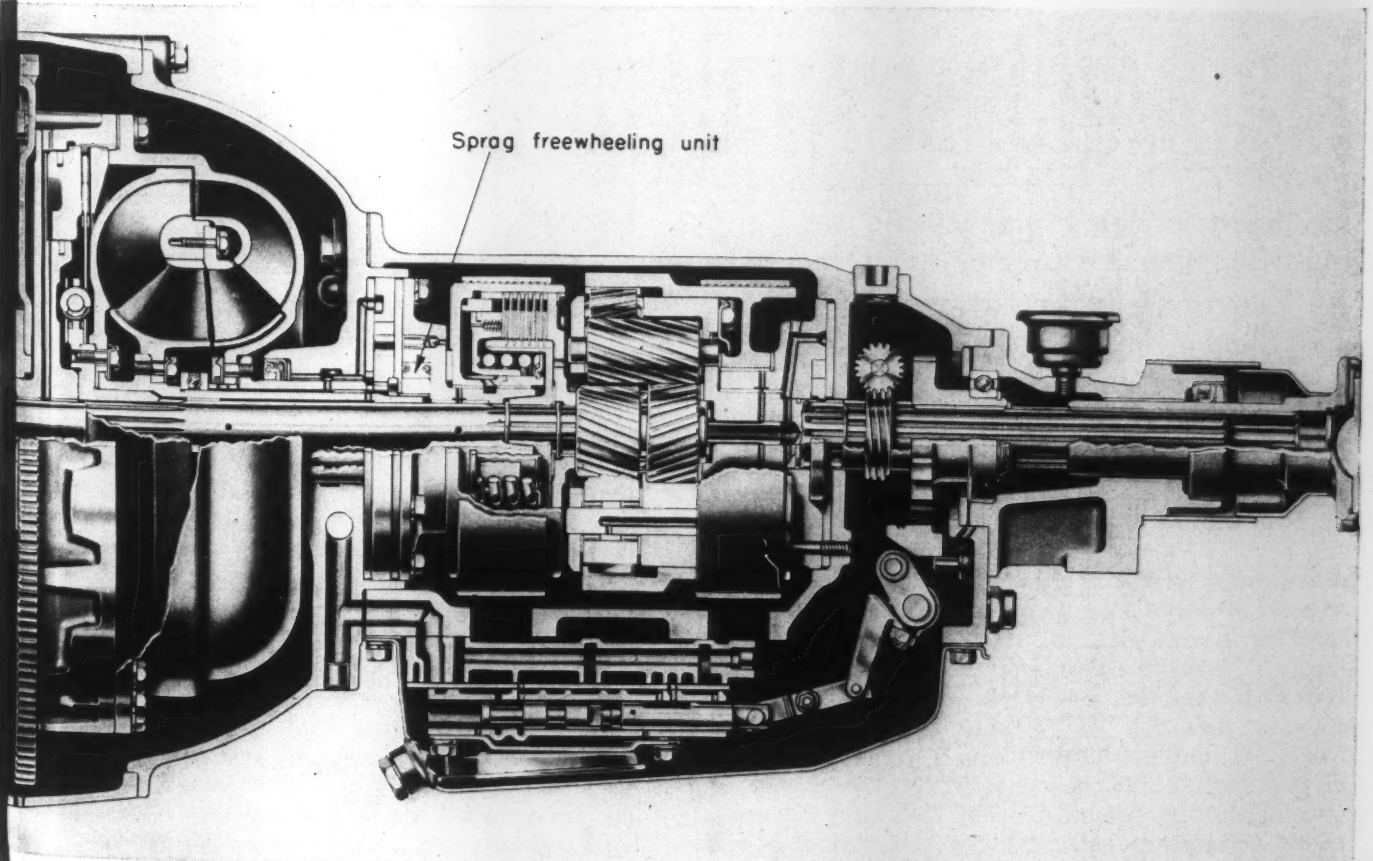
Under extreme overload, the roller clutch tends to slip. That is, the wedging angle becomes greater than the effective friction angle. When the torque is then reduced, the clutch re-engages and normal operation is restored.

The sprag clutch, under extreme overload, may have one or more sprags turned beyond the largest effective diameter. Then the clutch will lock in both driving and overrunning directions.

For high-speed freewheeling over extended periods, wear of the roller clutch leaves the rollers round, since they are free to rotate. Contact of the cam on the rollers during overrunning occurs on different points on the cam than when under load. The sprags are not free to rotate and may tend to be flattened by wear.

Since a sprag clutch is smaller in diameter for the

Photo, courtesy Packard Motor Car Co.



UNIVERSITY OF MICHIGAN LIBRARIES

same torque capacity, its surface speed in overrunning will be lower than that of the roller clutch, tending to give less wear.

On the roller clutch the outer race should be on the overrunning side, in order to avoid pressure of the rollers against the outer race because of centrifugal action during overrunning. On the sprag clutch, the inner race should overrun, since it is of smaller diameter and has the lower surface speed.

Applications: The field of application of freewheeling clutches has been extended with the development of more intricate automotive and aircraft propulsion drives. *Fig.* 6 shows a cross-section through the Packard Ultramatic transmission which uses a sprag freewheeling unit in the stator mounting of the torque converter. Thus, it provides the equivalent of a gear-shift in the torque converter and provides for high efficiency over a wide range of operation. The design principle of the sprag clutch permits machining accuracy and high surface finish without hampering mass production methods. In this application, economy and simplicity of the sprag clutch are decisive.

Aircraft propulsion drives use freewheeling units whenever two or more engines drive one propeller. Without such a clutch, a failure of one engine would put the load of the dead engine on the good one, and thus practically destroy its propulsion value. If each engine drives the propeller through an overrunning clutch, stopping one engine will not affect the operation of the other. Flight at half power, with one engine shut down is then possible.

This condition may be utilized to obtain better efficiency, particularly on gas turbine drives, since gas turbines operate at best efficiency near full load. For take-off, climbing, or high-speed flight, both engines are operating. For normal cruising, one engine is stopped and the other is operating at full load. The resulting increase in safety, improved fuel efficiency, and reduction of engine wear are worth many times the cost and weight of the freewheeling clutches. *Fig.* 7 shows a gear box for a twin gas turbine geared aircraft drive. The two freewheeling units for this drive, rated at 350 hp total at 2650 rpm, add only about 4.5 lb to this assembly.

In a similar way freewheeling units are applied on helicopter drives. Here the unit is interposed between the engine and the rotor drive (MACHINE DESIGN, April, 1951). For smaller helicopters the sprag clutch has found much use. With its ultimate capacity planned sufficiently high—several times the normal load rating—this clutch can be used with full safety.

Where the power ratings are high, from several hundred and up to thousands of horsepower, the number of sprags required would be too great to insure adequate distribution of load among them. For such applications the roller clutch is generally preferred.

Fig. 7—Gear box for a twin gas-turbine aircraft drive showing application of roller freewheeling clutches

Drawing, courtesy Convertawings Inc.

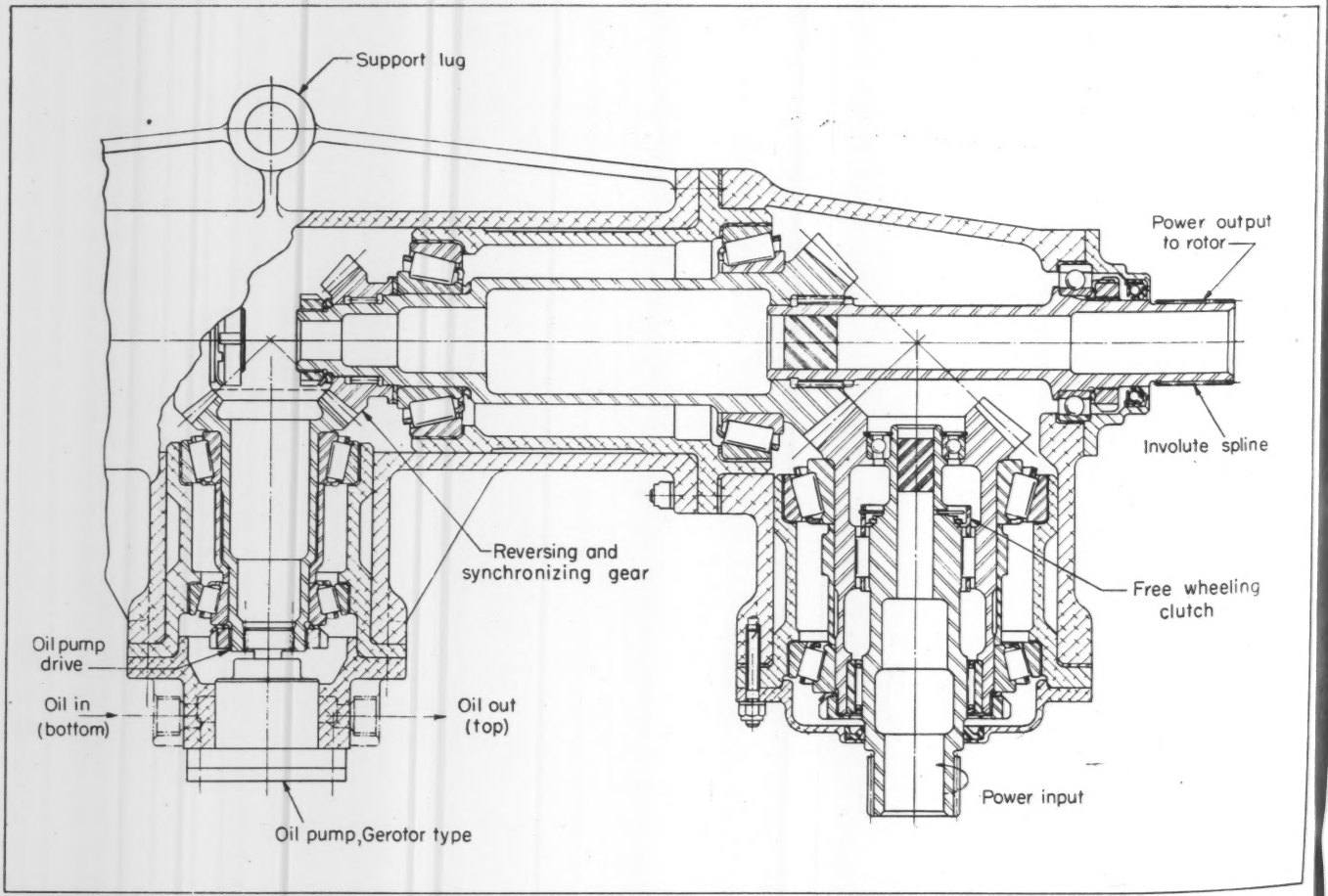


Fig. 1—View of indexing mechanism of coreblower. Drive latch can be seen at the left and the lock arm at the bottom

By Robert W. Ellms
Assistant Chief Engineer
Machine Div., Osborn Mfg. Co.
Cleveland, Ohio

PNEUMATIC GENEVA MECHANISM

. . . in new coremaking machine produces indexing motion by means of power cylinders

IN THE FIELD of foundry coremaking, it is desirable to have as many operations as possible performed mechanically. A mechanism to which prepared sand is fed that would produce cores suitable for dipping and baking without the need for any manual assistance by skilled operators would be desirable both from the standpoint of uniform quality cores and increased production. Such a machine, developed by Osborn Mfg. Co., combines the three main jobs in coremaking: (1) Blowing the core; (2) taking away filled core boxes and simultaneously bringing empty core boxes to the core blower for filling; (3) extracting the cores from the filled boxes onto dryer plates ready for processing.

Under the old system of making cores for automotive castings, approximately 30 block jacket cores were turned out by a coremaker in one hour. With this new machine, a worker can turn out 180 cores per hour. In addition to a 500 per cent increase in production, this new machine makes more accurate cores of higher quality than could be produced by older hand methods.

Essentially, this machine consists of three main mechanisms co-ordinated by fully automatic electro-pneumatic controls. The core blower utilizes compressed air to blow or drive prepared sand into conventional core boxes. A five-station turntable interlocked with the core blower is designed to bring empty core boxes to the core blower for filling and to take away the filled boxes. Interlocked and in sequence with both the turntable and core blower is a core rockover and core draw mechanism which

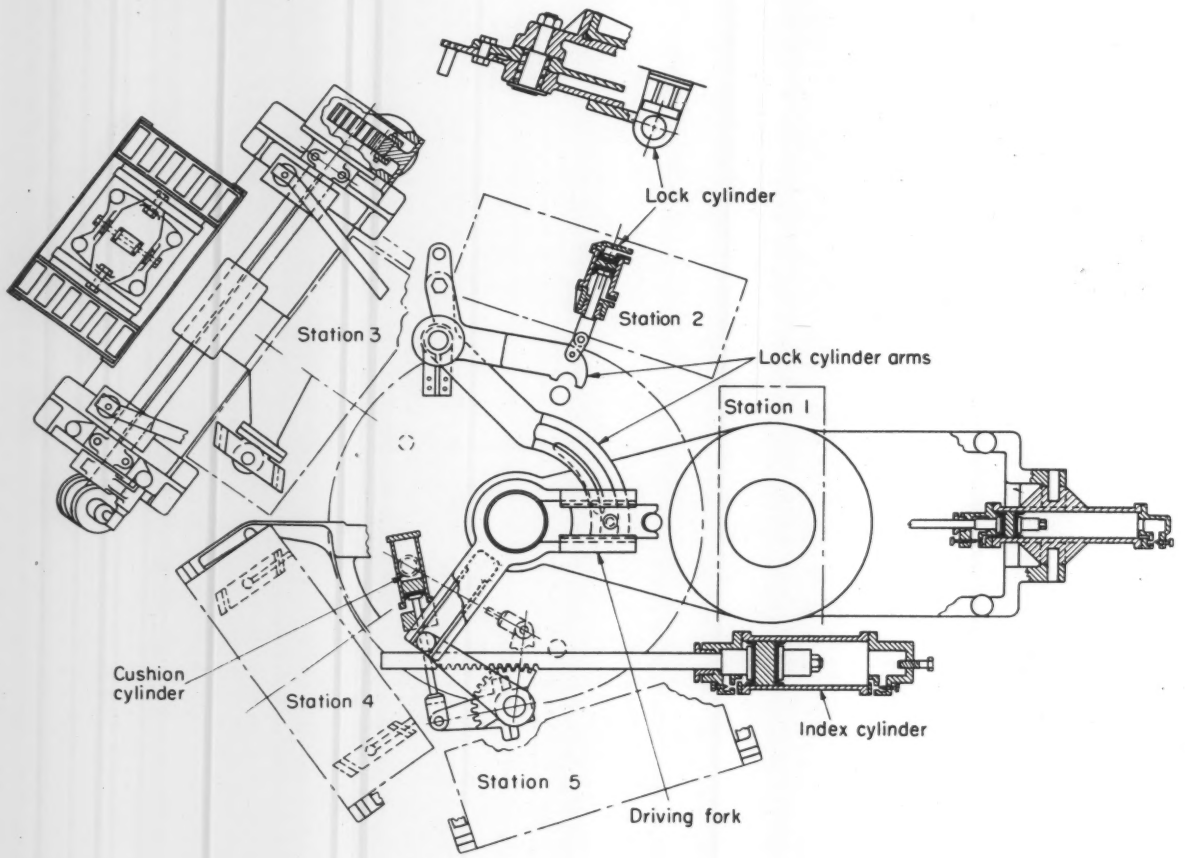
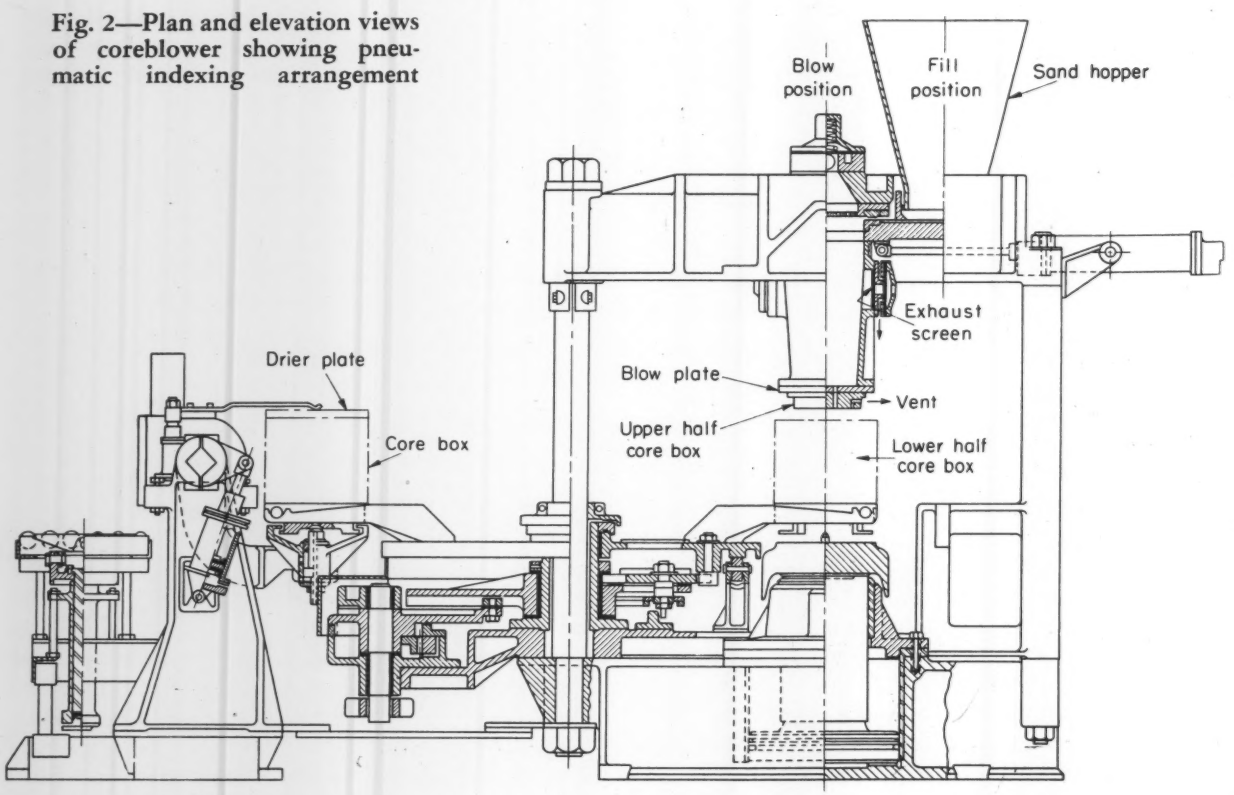


Fig. 2—Plan and elevation views of coreblower showing pneumatic indexing arrangement



serves to extract the cores from the filled boxes onto suitable drier plates. Pneumatic power and control for the complete unit are sequenced by an electric timer which opens and closes contacts previously set for proper operation of solenoid air valves, which in turn, control the various operations.

The unique feature of this machine is the pneumatic table drive, *Fig.* 1, which with ordinary cylinders produces table indexing similar to that generally requiring a Geneva drive. The turntable indexes one-fifth turn at each cycle of the timer and it is possible to have the turntable rotate clockwise or counterclockwise as desired.

In operation, with air supplied to the index cylinder, *Fig.* 2, by a four-way solenoid valve, the piston is driven to the right. This, in turn, drives the rack to the right, rotating the gear segment and arm. The roller on the end of the gear arm is permanently engaged in the slot of the driving arm and carries it from left to right in the manner of a Geneva motion. The driving arm has the same center of rotation as the turntable but both can turn independently or together, as required during the operation.

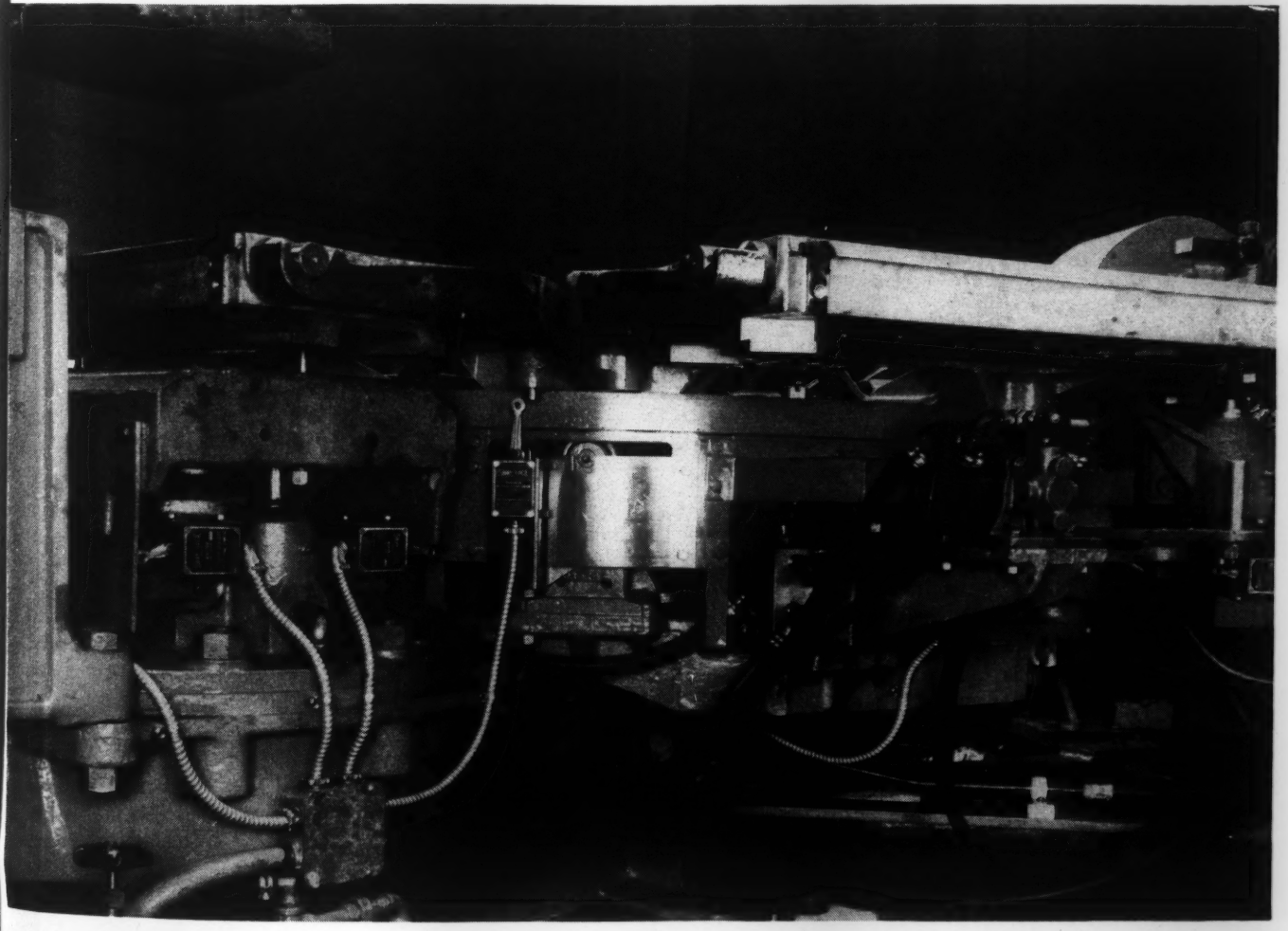
In order to produce a steady and controlled driving motion, a cushion cylinder which rotates about a vertical axis, has its piston driven back for the first half swing of the gear arm through another arm keyed to the same shaft, *Fig.* 2. Fluid taken in the front end of this cylinder during the first half of the stroke of the power cylinder can be restricted or controlled during the expulsion of the fluid for the last half of the stroke, thereby acting as a brake on the swing of the arms to control the momentum of the moving parts acquired during the power stroke.

The right-hand portion of the driving fork carries a tongue, or slide member, with a notch in its right-hand end which engages station pins on the turntable. Thus for counterclockwise rotation of the turntable, as the arm swings from left to right, Geneva motion fashion, the tongue drives the table one station (one-fifth turn).

In and out motion of the tongue, or slide, is obtained by means of the lock cylinder mechanism. During the index power stroke, the piston of the lock cylinder is back as shown in *Fig.* 2. At the instant the turntable comes to rest, the piston in the lock cylinder moves forward, causing the notch arm to engage the turntable pin, locking the table. Since the lock cylinder arms move together, the driving tongue is automatically retracted from its pin. To continue the cycle, the index cylinder reverses and returns the driving fork to its original position ready for engagement of the next turntable pin.

Supplementing the sequential pneumatic controls, limit switches, *Fig.* 3, and pressure switches are provided to protect all important operations on the ma-

Fig. 3—Side view of machine showing various limit switch sequence controls



UNIVERSITY OF MICHIGAN LIBRARIES

chine. Should the control timer be improperly adjusted, or should an operation take longer than anticipated, the electrical circuit is prevented from being completed because the circuit is broken by a protecting limit switch. A complete wiring diagram is shown in *Fig.* 4.

Assuming the timer contacts have been properly adjusted and one complete cycle is to be made, the main electrical supply switch is closed and the first operation takes place, indexing one station. Protecting limit switches *LS*-1 and *LS*-2 are closed when the rollover table on the rollover core draw mechanism is down in its proper place. Switch *LS*-3 must be closed, assuring that the table lock is out and *LS*-4 must also be closed when core blower table is completely in down position. Then the index solenoid air valve delivers compressed air to the index cylinder and causes the table to rotate one-fifth of a revolution. During this interval the sand reservoir moves from the blow position to the fill position and back again. Current flows to the carriage operating cylinder solenoid valve during this time provided *LS*-6 is closed. *LS*-6 is another limit switch which is closed only when the core blower table is completely down.

Thus, the table has indexed once and the sand reservoir has shuttled once. Now if the manual core blower and rollover start switches are closed, valves which control the core blower and rollover mechanism operate. *LS*-5 is a limit switch which indicates the turntable is in the correct position for the blowing and rolling over operations. When *T*4 closes and *LS*-5 is closed, current is sent to the table lock solenoid valve and with the table in the locked position, *LS*-3 is opened and *LS*-3*A* is closed. This is a double-throw switch and positively indicates that the table lock is fully in. Thus current will flow through *LS*-7, a limit switch which cannot close until the reservoir is in the blow position. Now since the core blower start button is closed, current will flow to *LS*-8, a limit switch which is closed only if a platen is in position for vertical clamping.

Current flows through coil for control relay 1, closing its contacts *CR*-1. The vertical clamp piston rises and clamps the platen and core box to the blow plate. It should be noted that limit switches *LS*-2 and *LS*-4 are double-throw switches and should the core blower and roller stop button be pressed during this last operation, current will continue to flow through *LS*-2*A*, (closed when rollover table is up) and *LS*-4*A*, (closed when core blower table is up) until these separate operations are completed. This is a safety measure to insure that the operator cannot interrupt the blowing or rollover action until they are completed. Also the core blowing action and rollover action will stop when completed and will not repeat until their start buttons are pressed again.

The vertical clamp piston rises and clamps the platen and core box to the blow plate. The clamp pressure switch is set so that when sufficient pressure has been reached, the circuit is closed, *T*6 is also closed, and current will flow to the blow solenoid valve. After the core is blown and the reservoir exhausted of air, the vertical clamp is lowered when *T*5 breaks circuit and *CR*-1 contacts open.

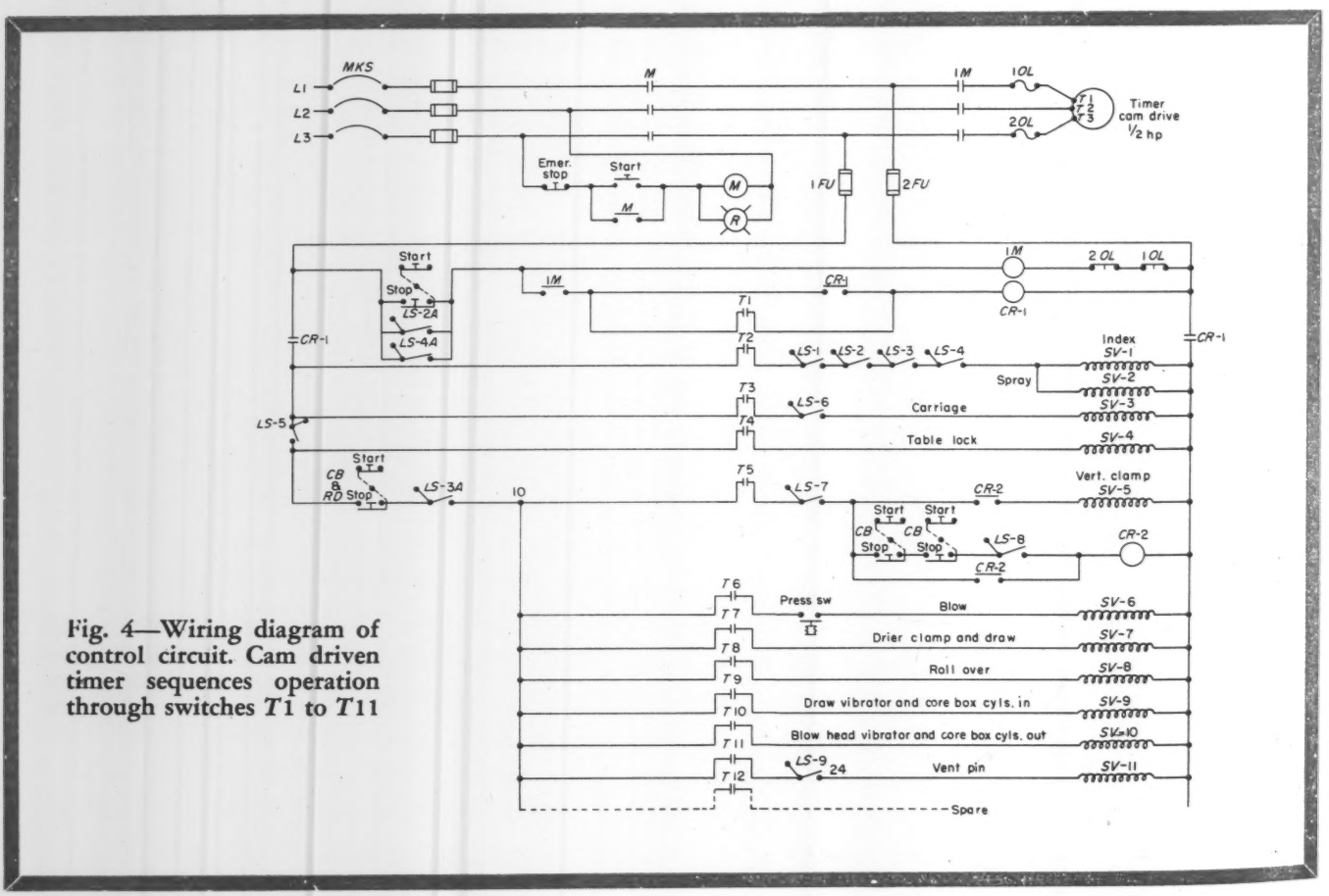


Fig. 4—Wiring diagram of control circuit. Cam driven timer sequences operation through switches *T*1 to *T*11

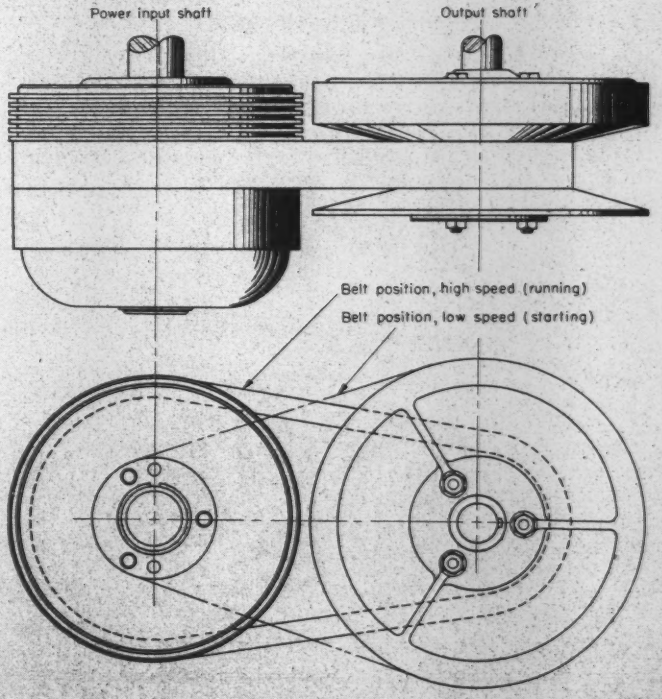
ALL-MECHANICAL Torque Converter Drive

By L. D. Thostensen
Vice President and Chief Engineer
Salsbury Corporation
Los Angeles, Calif.

UNIVERSITY OF MICHIGAN LIBRARIES

Fig. 1—Above—Cutaway view shows construction detail of the Salsbury automatic transmission. Drive belt is in starting position

Fig. 2—Below—Starting and full running positions of the drive belt represent an overall change in speed ratio of 4.5 to 1



IN MACHINERY and vehicle drives requiring automatic adjustment to maintain balance between the driven load and the driving engine or motor, the automatic transmission shown in *Fig.* 1 provides a simple solution. It has proved useful in drives where loads in excess of power unit rating are encountered intermittently, and also for overcoming high initial or starting torque. Typical applications include agricultural machinery, vehicles, portable industrial and construction machinery, and refrigeration compressors.

A recent trend, in these fields in particular, has been toward weight reduction of both machine and power plant. While portability and mobility have thus been enhanced, the reduced inertia of moving parts usually has resulted in a greater tendency of load fluctuations to impose overload on both the driving and driven mechanisms.

Operating characteristics of the Salsbury automatic transmission, which is in reality an all-mechanical torque converter, are: gradual pickup, smooth acceleration, automatic relief of operating overloads, and stepless speed change resulting in minimum wear and tear on all moving parts.

How the transmission operates without manual

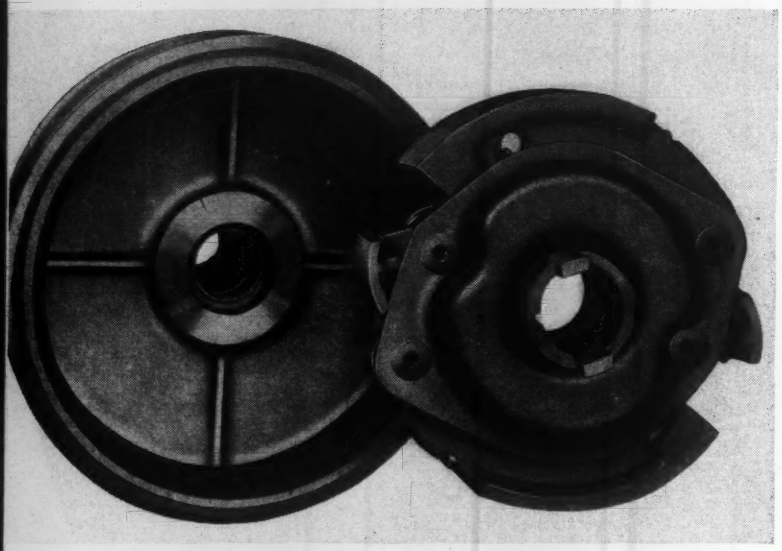
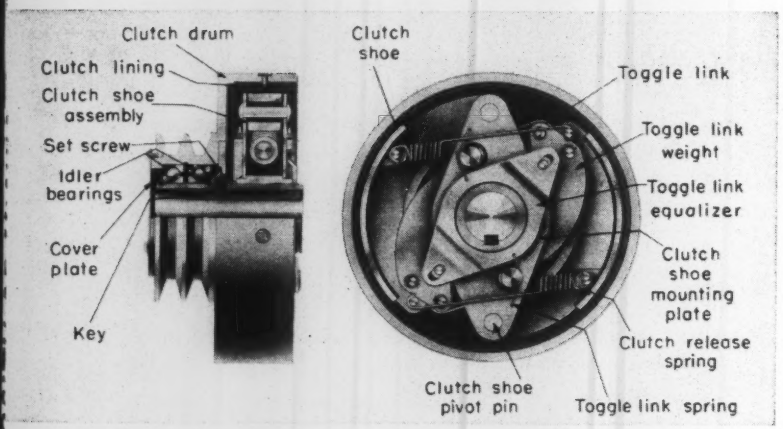
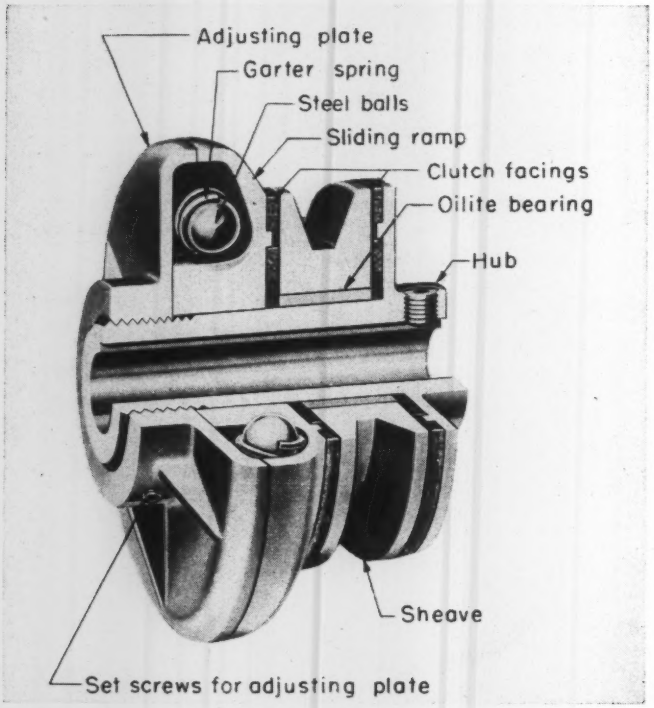


Fig. 3—Above—Centrifugal clutch assembly used in the automatic transmission is a separate unit. Ribbed outer surface of the drum adds strength and helps dissipate heat





control can be visualized by study of *Fig.* 1 which, incidentally, shows the unit in starting position for maximum torque output. The centrifugal clutch and primary pulley, comprising the input section of the drive, are mounted on the power shaft by means of an adapter sleeve. As can be seen, a single V-belt connects the input and driven pulleys. Each pulley has one movable flange which, during operation, is adjusted automatically in response to load requirements.

Primary control of the unit after the clutch has engaged the input pulley is effected by the mechanism contained in the driven pulley. As the speed of the output shaft increases after starting, centrifugal force of the weighted linkage in the driven pulley overcomes a static spring force against the movable flange, causing the flanges to separate.

Constant belt tension is maintained by the input pulley mechanism as the driven pulley flanges separate in response to output shaft acceleration. To accomplish this, the movable flange of the input pulley moves toward the fixed flange under spring pressure augmented by force derived from the weighted linkage inside the housing. The contour of the curved surface on which the linkage roller weights operate is designed to provide constant tension-sensing ability in the primary pulley and to insure complete reset to starting position when the drive is stopped.

The co-ordinated positioning of the movable flanges according to load and output speed thus effects a stepless range of speed ratios from minimum to maximum in the transmission. Belt paths in the extreme ratio positions are shown in *Fig.* 2. Since the normal

Fig. 4—Left—Automatic clutch unit has 300-rpm differential between "lock-in" and release speeds. Equalizing arrangement in toggle linkage insures simultaneous operation of shoes

Fig. 5—Left, below—Simple low-cost clutch is used for comparatively light drive loads. Construction permits renewal of clutch facing disks without removal of hub from driveshaft

belt position for full capacity running load is the "high" position, it is evident that a sudden overload tending to slow down the drive causes the pulleys to respond by reducing the ratio, thus avoiding engine or motor overload and possible stalling.

Clutch drums are lined with heavy-duty asbestos lining and the assembled units are balanced to avoid vibration. The centrifugal clutch is similar to those available for single-speed drives in which, at predetermined speeds, "lock-in" arrangements provide slip-free engagement to insure full power transmission at rated speed. The clutch shown in *Fig.* 3 is for 2 to 7-hp drives while the one in *Fig.* 4 is for 7 to 15-hp applications.

In comparatively light drives where space is limited, or cost must be low, the clutch illustrated in *Fig.* 5 is often adequate. In operation, the spring-encased balls are thrown outward by centrifugal force, wedging the disk facings against the friction surfaces of the drive pulley.

Selection and Application of

CONTROL TIMERS in Machines

By V. C. Blecker
Electrical Engineer
Eagle Signal Corp.
Moline, Ill.

USE of timers on machines for high production rates and accurate control of quality is steadily increasing. Modern production machines have electric, pneumatic or hydraulic "hands" which must be controlled by electric "brains". Where operations require specific time intervals to perform particular functions, the use of an electric timer insures consistent repeat operations.

Reduction of product cost may result not only by the direct operation performed by the timer but also by the indirect benefits that result from a steady rhythmic flow of production. Assembly workers on piece rates may speed up their work at the expense of proper quality. A timer used in some part of the operation can pace the work at optimum speed. Uniform cycles may also be beneficial on some types of machines. For example, on a molding press it is necessary to operate at a constant cyclic rate so that the volume of plastic flowing through the machine is constant to maintain a uniform temperature.

Basic knowledge of timers is important to the machine designer. From the many different principles

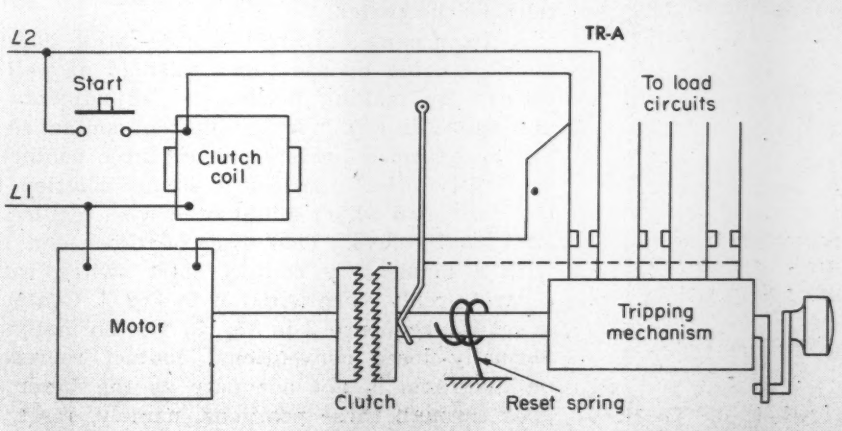


Fig. 1—Schematic diagram of a single-cycle timer

UNIVERSITY OF MICHIGAN LIBRARIES

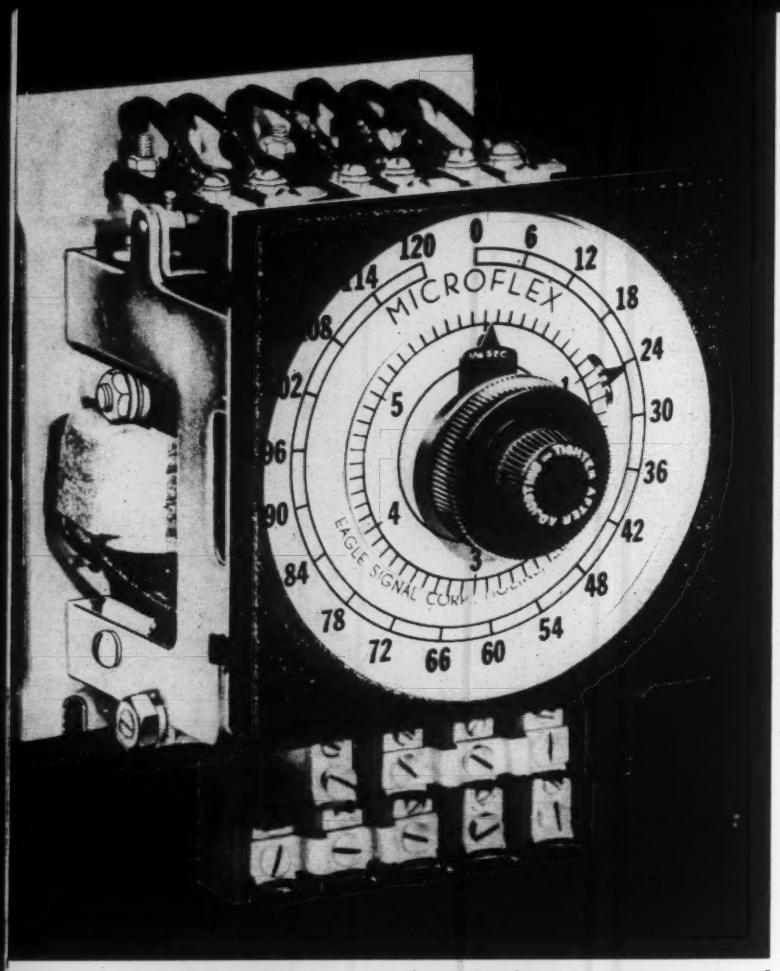


Fig. 2—Single-cycle timer having three contacts and micrometer timing dial for precision timing

Sequence Number	Switch Positions		
	Reset	Timing	Timed-Out
1	○⊣⊢○	○⊣⊢○	○—●—○
2	○⊣⊢○	○—●—○	○⊣⊢○
3	○—●—○	○—●—○	○⊣⊢○
4	○—●—○	○⊣⊢○	○—●—○
5	○⊣⊢○	○—●—○	○—●—○
6	○—●—○	○⊣⊢○	○⊣⊢○
7	○⊣⊢○	○⊣⊢○	○—●—○

Fig. 3—These different contact operations are obtainable on timers having contacts actuated by the clutch coil as well as by the timer motor

of operation as well as many different uses, proper selection must be made of a timer that will function dependably and accurately in the machine control system and at the same time provide flexibility for possible changes in the sequences of operations. Obviously a timer designed for occasional use in amateur photography would not give satisfactory service in an industrial machine operating several thousand cycles per day. A timer for industrial use must be designed and constructed to give dependable service. The loss in production from a single timer failure may be several times the total cost of the timer involved. Also, the designer should not overlook coordinating mechanical and hydraulic circuit design with the electrical controls. Often, no thought is given to electrical controls until the machine design is otherwise completed. The resulting electrical control circuit which is then required may be unnecessarily complicated and expensive.

The following advantages are applicable to synchronous motor driven timers in general:

1. Can be used for timing periods from a fraction of a second to months merely by using different gearing
2. Provide accurate and consistent repeat timing
3. Timing dials can be marked in units of time
4. Are unaffected by 15 per cent voltage fluctuations and normal temperature variations
5. Have sufficient power to operate heavy-duty contacts.

Timer motors are sometimes referred to as clock motors. However, these motors used in industrial timers are usually more heavily constructed, have a higher torque rating, and are more thoroughly tested than motors used in clocks.

Single-Interval Timers: Single cycle, or reset timers as they are often called, are started by closing a pilot switch, run through a predetermined time period and return to their starting position. The pilot switch must close again before the timer will go through another cycle.

In *Fig.* 1 is illustrated the basic elements of a synchronous motor timer which drives a contact tripping mechanism through a solenoid-operated clutch. When the clutch is disengaged, the reset spring returns the tripping mechanism to its starting position. The starting position may be varied by an adjustable stop or dial to change the timing period. Design details differ considerably with various manufacturers. One type has a clutch with teeth cut for positive driving action. Others use a friction drive such as a cone surface or washers of friction material between two disks. Another uses a differential locked for driving engagement by a solenoid.

The simplest reset timers use a snap-action switch which is actuated at the end of the time period. When the clutch coil is de-energized, the timer resets and releases the switch.

A timer more universal in application has its contacts actuated by the timer solenoid as well as the motor. By making mechanical adjustments to the unit shown in *Fig.* 2, seven different contact sequences can be obtained on any one of three contacts. This versatility often provides a simple solution to control problems which might otherwise require several additional relays. This type of timer can be used with a momentary contact start switch without a separate relay when wired as in *Fig.* 1. Contact *TR-A* is set for sequence 2 in *Fig.* 3. The normally-open or normally-closed conventional contact representation on diagrams is not adequate as the timer contact goes through three positions, namely, reset, timing, and timed out. Therefore a symbol such as *O-C-O*

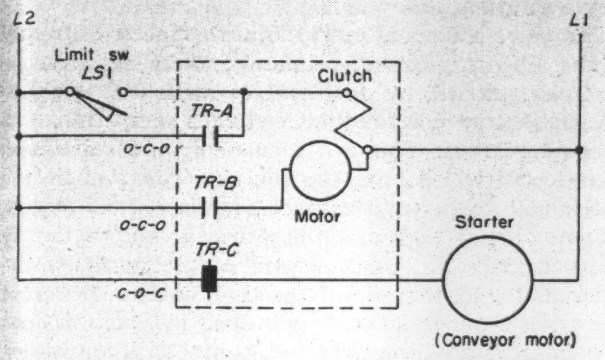


Fig. 4—Circuit for automatically restarting a machine stopped by a limit switch

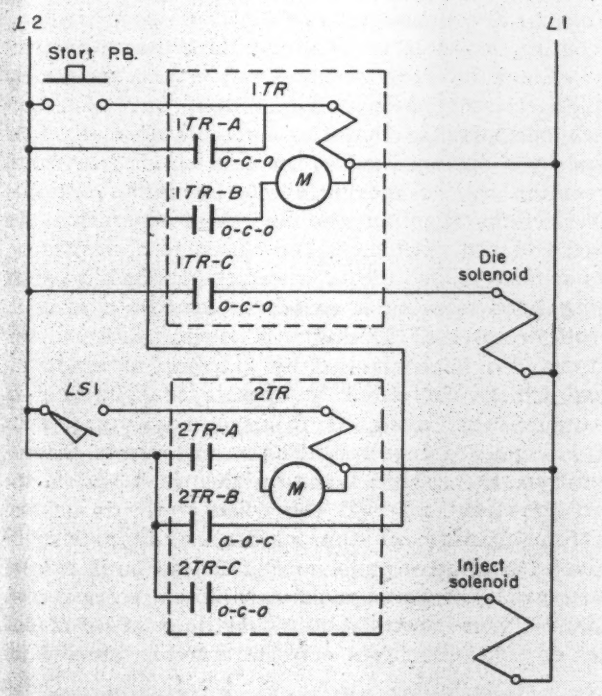


Fig. 5—Circuit for timing two intervals in sequence used on a molding press

can be used to indicate in which positions the contact is open and closed.

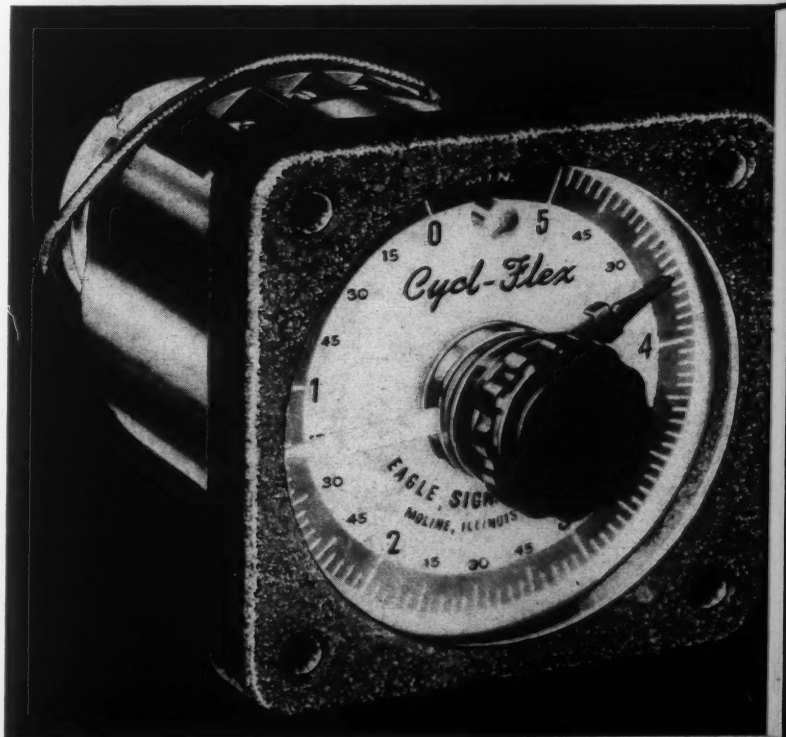
Closing the start pushbutton in *Fig.* 1 energizes the clutch coil which locks in through its holding contact *TR-A*. This same contact *TR-A,* which was closed by the clutch coil, is tripped open by the motor at the end of the time cycle. The clutch coil is then de-energized and the timer resets. *Fig.* 4 is an example of a simplified control circuit made possible by proper use of the different contact sequences available. This circuit is used to stop a motor-driven machine upon actuation of a limit switch and then restart it automatically after a predetermined time set on the timer. For example, on a barrel scrubbing machine, a barrel is moved from one station to the next by a chain conveyor. A timer is used to stop the barrel in each position for a predetermined number of seconds. Or, the circuit may be used on a baking oven having trays on a revolving reel. The reel must stop for a predetermined time as each tray comes in front of a door for loading. Another use is an index table for a machine tool or heat-treating machine which must stop in each position for a predetermined time.

A limit switch *LS*1, *Fig.* 4, is actuated by the conveyor of the barrel scrubber in each position in which it is to stop. This energizes the timer clutch coil which closes contacts *TR-A* and *TR-B,* contact *TR-C* opening to stop the conveyor motor. If the conveyor coasts past the limit switch *LS*1 and releases it, the conveyor cannot restart as the timer is held energized by contact *TR-A.* When the timer times out, contacts *TR-A* and *TR-B* open while *TR-C* closes. This restarts the conveyor motor and the sequence is repeated. Note that the timer motor is controlled through a separate contact, *TR-B* instead of *TR-A.* Therefore if the conveyor should stop, holding *LS*1 closed, the timer motor is de-energized by contact *TR-B* when the timer times out. If the motor were connected to *TR-A,* it would have remained energized and stalled as long as the limit switch remained closed. Stalling synchronous timing motors does not damage them electrically but it does impose a severe load upon the gearing which ultimately may cause failure.

How two timers can be used to perform a sequence of operations is illustrated in *Fig.* 5. Also, one timer, 1*TR,* serves two functions, being used first as a holding contactor and later as a timer. This circuit is used on molding presses where one timer times the interval when an injection ram is forward to inject plastic into the die and another timer holds the die closed long enough for the plastic to harden.

Pressing the start button energizes 1*TR* which locks in through its holding circuit 1*TR-A.* 1*TR-C* closes to energize a solenoid valve to close the die. No timing occurs on 1*TR* even though it is energized, because its timing motor does not receive power. 1*TR*

Fig. 6—Timer for panel mounting with cycle progress pointer



UNIVERSITY OF MICHIGAN LIBRARIES

is used as a holding contactor to hold the die solenoid energized. When the die is fully closed, a limit switch *LS*1 closes to start 2*TR*. This energizes the valve for a preset time for the injection of the plastic. When 2*TR* times out, it closes its contact 2*TR-B* which starts the motor on timer 1*TR*. After the time delay on 1*TR*, 1*TR-A* opens to reset 1*TR* and open 1*TR-C*. The press opens, both timers reset, and the system is ready to repeat.

Operating the timer motor independently of the clutch coil to delay the timing action is useful in many different timer circuits. On a baking oven, for example, the timer clutch coil can be energized from a pushbutton to close the timer contacts and open the fuel valve. It is required that timing does not start until the oven reaches the proper temperature. A thermostat wired into the timer motor circuit to start the motor when the thermostat closes is a simple solution.

The valve solenoids in *Fig.* 5 are connected directly to the line through the timer contacts to decrease the load carried by the control switches. Neither the pushbutton nor the limit switches carry the valve solenoid current. This can be done only when timers are selected which have the contacts operated by the clutch coil to provide contact sequence 2 in *Fig.* 3.

Some timers have one set of contacts operated by their clutch coils and a second set actuated by the timer motor at the end of the time period. Different operating sequences can be obtained by combinations of connections between the two contacts. *Fig.* 6 illustrates a timer having a sealed case in which the two sets of contacts are connected to terminals. Four different contact actions are possible by using different electrical connections, *Fig.* 7.

It is important in some applications that a momentary voltage interruption does not return the timers to their starting position. Timers may have reversed-clutch operation so that the clutch is normally held closed by a spring. Such a timer does not reset until the clutch coil is energized by closing an external pilot switch. Opening the switch de-energizes the clutch coil and re-engages the clutch to start timing. This scheme is also useful where the timer is to start timing upon opening a switch instead of closing it.

Multiple-Interval Timing: A series of timed operations can be controlled by a group of single-interval timers connected to operate in sequence. In one centrifugal designed to crystalize sugar, four timed steps are required. The first controls the acceleration, the second turns on the wash water, the third times the interval the wash water is on and the fourth turns off the machine and applies the brake. The control panel in *Fig.* 8 was built to control a group of three machines. Each vertical row of four timers controls the four timed steps of one machine. The machines can therefore be started in-

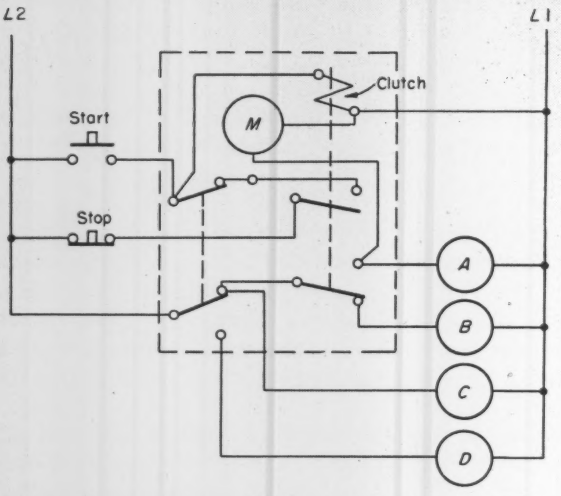


Fig. 7—Above — Circuit diagram of timer in *Fig.* 6. One set of contacts actuated by clutch coil and another set by the timer motor provides four possible load circuit connections

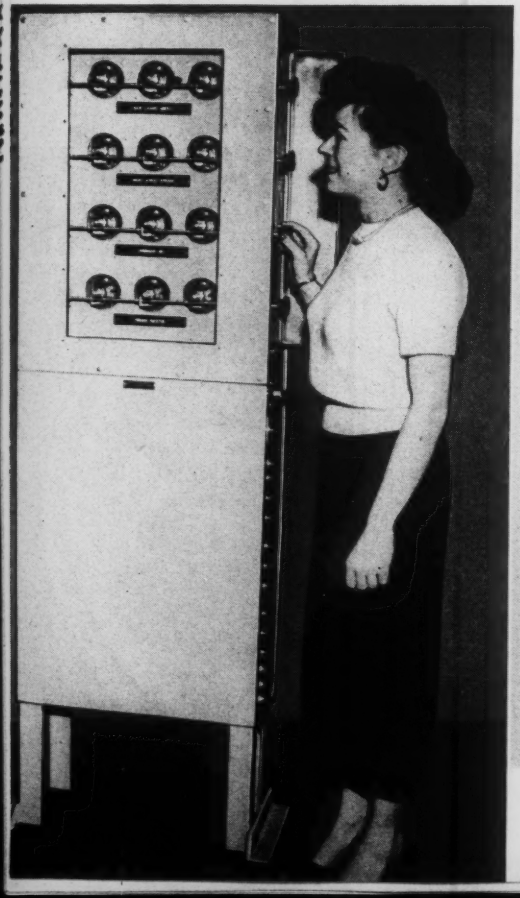
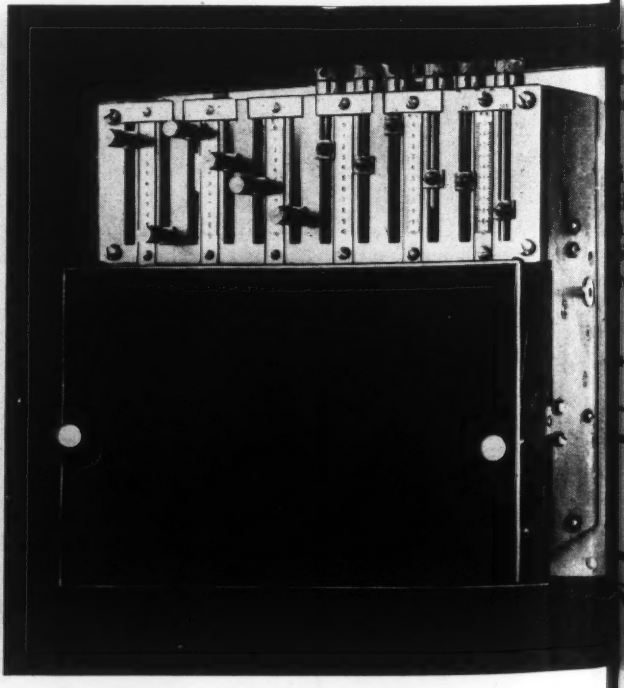


Fig. 8—Left—Control panel for three sugar centrifugals. One knob adjusts timers for three machines simultaneously. Solenoid valves for pneumatic operation of machine are in base of cabinet



dependently with one being unloaded while the other two are operating. The timer knobs in each horizontal row are geared to one shaft with a single knob on the side of the case. In this way, timing of each function on all three machines can be changed simultaneously and the machines will always operate with the same time intervals.

Multiple time periods can also be controlled by a single instrument shown in *Fig.* 9. This utilizes the same principles shown in *Fig.* 1 although details of the contact tripping mechanism and contact setting differ from single-interval timers. Each contact has an ON and an OFF slide setting to close and open the contact at any point within the time scale. The slide settings can be mounted on a vernier screw when easy adjustment and accurate setting are required.

These timers are ideal for timing heating and quenching on induction heaters, flame hardening machines, mixing controls, sequence feeding of material into batches, sequence dispatching over conveyor systems, molding presses, etc. Its flexibility of time adjustment can best be described by referring to *Fig.* 10, which is an example of a possible contact sequence. It would require eight single-interval timers to provide the same operation provided by one multiple-interval timer.

Some machines require a series of fixed intervals for starting, a variable running time, and then another series of fixed intervals for stopping and unloading. This can be controlled by a combination of a multiple interval timer and a dial type single interval timer. The multiple-interval timer performs the starting sequence of the machine and closes a contact to start the single-interval timer. The multiple interval timer stops until the end of the period set on the dial of the single interval timer when it restarts and completes the balance of its operations.

Cam type multiple interval timers are available at a lower cost and can be used where the timing will not be adjusted frequently enough to require a calibrated scale. The cams are normally set at the factory to provide the timing specified by the purchaser but they can be reset in the field if necessary.

Repeat-Cycle Timers: Repeat-cycle timers go "round and round" closing and opening their switches in a continuously repeating sequence. The simplest form consists of a gear reducer motor with a cam on its output shaft which closes and opens a switch once for each revolution of the cam. The cam may have an adjustable segment to vary the portion of each cam revolution during which the switch is closed. The cam is sometimes calibrated in per cent, to permit setting an exact percentage of the cam revolution that the switch is closed.

The cam speed is determined by the gearing. A cam with several notches can be used where the switch must operate faster than the speed of the cam. It is apparent that a large number of gear ratios is required to meet the needs of machine controls. A wire forming machine may require a timer to operate two valves alternately every second while a dust collecting system may require a timer for cleaning the bags once a day. Timers are customarily standardized in certain adjustable ranges such as 1 to 6 minutes, 3 to 18 minutes, 5 to 30 minutes, etc. Time cycles within each range can be secured by changing the gear on the cam shaft. An idler gear on a moveable segment provides a convenient means of meshing with different size cam shaft gears. Some timers have two concentric idler gears, one twice as large as the other. In these types, two time cycles, one double the other, can be obtained with each change gear depending upon which idler gear is driving it.

Multiple-circuit repeat-cycle timers, *Fig.* 11, can be built by lengthening the cam shaft and adding as many switches as required. Using a spiral cam arrangement as detailed in *Fig.* 12 has advantages in multiple-circuit timers particularly where several circuits must operate in close sequence or must be

g. 9—Left—Multiple circuit timer for multiple tervals. ON and OFF settings of each con-ct are adjusted by slides on the linear scales

g. 10 — Below — A typical hedule of operations which n be set up on the timer in g. 9. Reset time required om full setting is 0.4 seconds

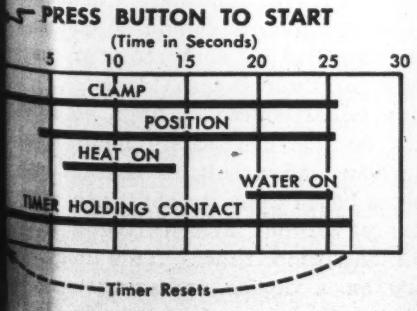
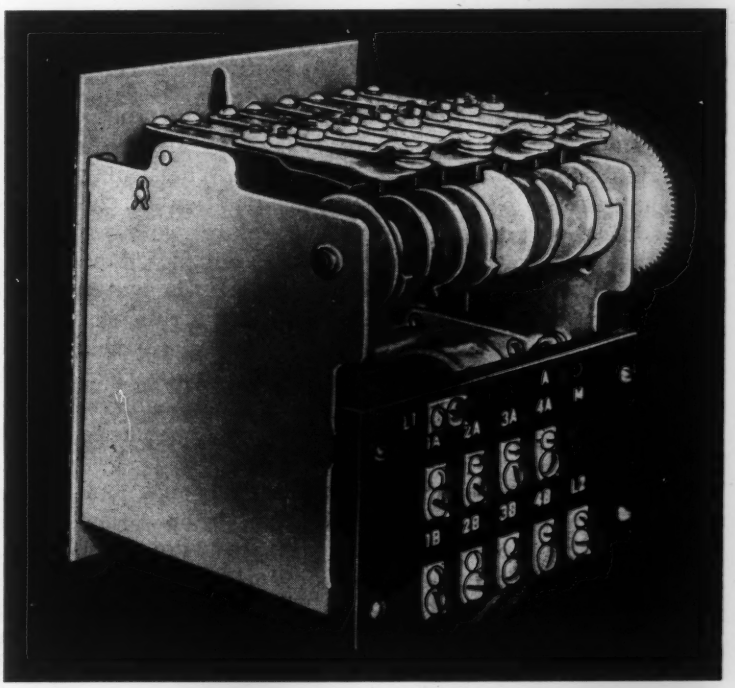


Fig. 11—Right — Multiple - circuit repeat-cycle timer



opened or closed for a short percentage of the cycle. Each switch has two spiral cams. The drop-off on one controls the point of switch closing and the drop-off on the other controls the point of switch opening. Since each drop-off has a sharp edge, the point of switch actuation can be set accurately. Only a few thousandths of an inch cam movement is required to close and open the switch.

Multiple-circuit timers, when desired, can be used as single-cycle timers. On a certain tire making machine, for instance, a timer having twenty circuits is required. The timer operates through one cycle each time the operator presses a foot switch as shown in the partial circuit in *Fig.* 13. Pressing the foot switch (start) locks in relay *CR* and starts the timer motor. During the camshaft revolution, the double-throw switch *PT*-1 is actuated, which releases relay *CR*. The timer motor continues to run until one revolution of the cam shaft is completed, when *PT*-1 is released and the timer motor stops. Many variations of this circuit are possible for specific applications.

The dial type repeat-cycle timer in *Fig.* 14 has

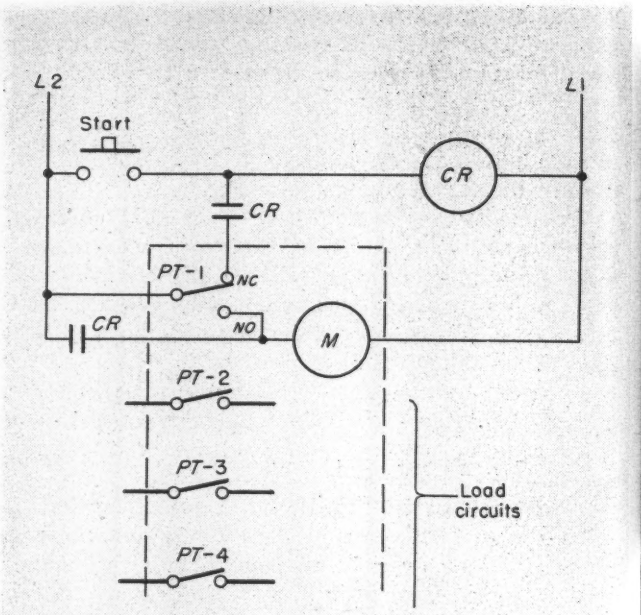


Fig. 13—Circuit to limit a repeat-cycle timer to one cycle operation

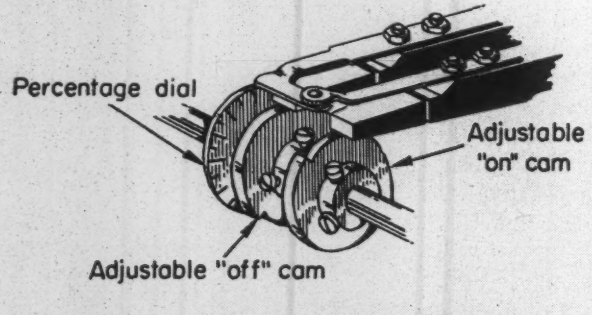


Fig. 12—Timer contacts operated by spiral cams provide accurate operation and permit short ON or OFF settings

the ON and OFF time adjustable on a dial. A unique mechanical reversing scheme is used to eliminate changing gears to vary the time cycle. The timing mechanism rotates clockwise to the position of the ON setting and then reverses and rotates counter-clockwise to the position of the OFF setting. Each time the mechanism passes O on the dial, the switch is closed or opened. This has a continuous range of adjustment and can be applied wherever a variable ON-OFF cycle is required. It is ideal for applications such as chemical feeding into a water treatment system where the amount of chemical feed must be varied frequently.

Manual Timers: Manual timers require some manual operation on the timer to start them in operation, *Fig.* 15. A pointer is turned to the desired time setting and a synchronous motor or spring-driven escapement returns the pointer to O. The timer switch remains closed until the pointer returns to O.

These types are used extensively in the home for washers, sun lamps, dryers, etc., but have rather limited use in machine control because of the time lost by the operator in setting each cycle. There is also a chance of error if the pointer is not set to the correct time for repeated cycles. They are satisfactory where the timing of each operation is different and the operator would have to set the dial anyway.

The use of a manual timer as a time accumulator to indicate life of cutting tools is one unusual use. The operator sets the timer for the correct tool life before resharpening is required. The timer is connected to run when the tool is cutting to accumulate the total cutting time of the tool. A warning signal is given near the end of the cycle. If it is not replaced within this warning time, the machine is automatically stopped. The timing motor must be selected to give little coasting upon each stopping; otherwise the error caused by accumulative coasting over a large number of starts and stops would defeat the purpose of the timer.

Timer Contact Ratings: The selection of a timer with heavy-duty contacts will often eliminate using contactors to control the load circuits. Most industrial timers will handle control circuits and solenoid valve loads direct. However in each case the inrush load to solenoid valves and motors should be checked. Motors are usually controlled by contactors or magnetic starters because of their inrush loads.

Two timers having equal contact ratings stamped on their nameplates do not necessarily have equal ability to handle a given load circuit. A contact may be rated at 20 amperes based upon its ability to carry this load continuously without overheating and to interrupt it several thousand times. This may be entirely satisfactory on a device operating once a day but not on a timer that must interrupt its load

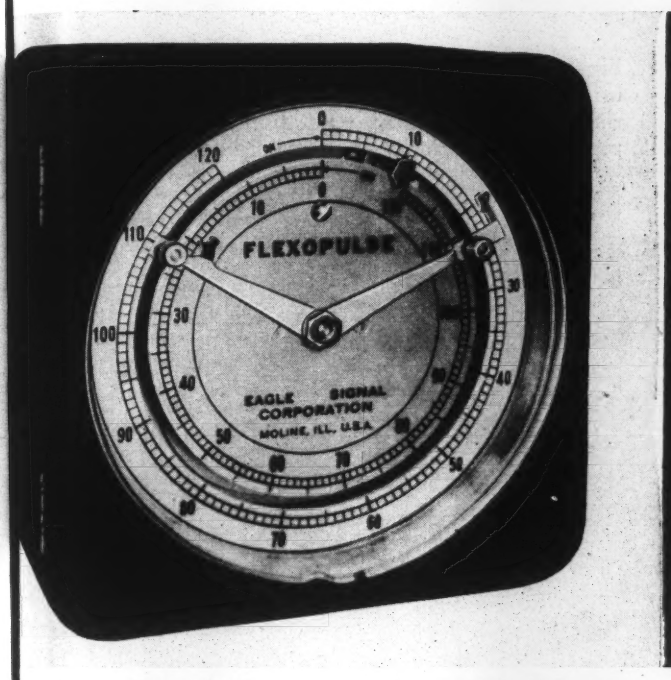


Fig. 14—Repeat-cycle timer with dial adjustment of the ON and OFF intervals

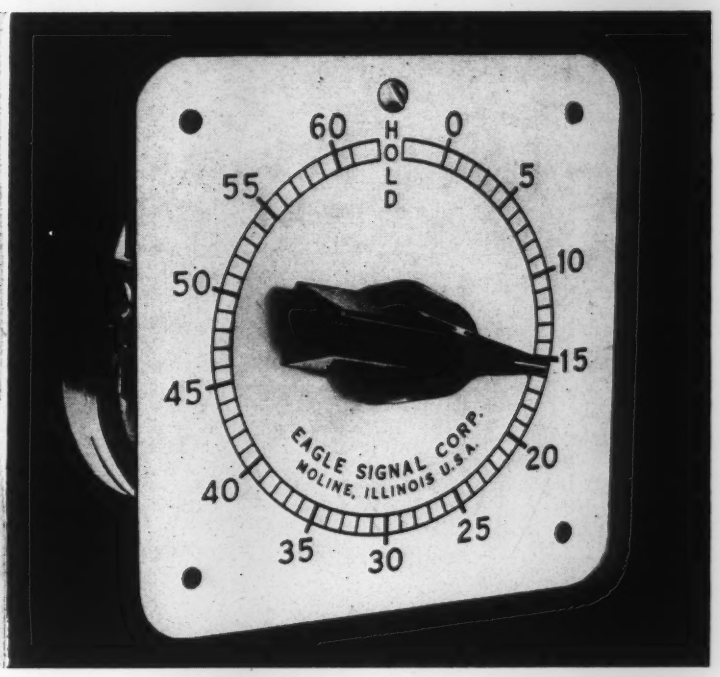


Fig. 15 — Manual timer started by turning knob to required time setting

circuit several thousand times a day. The continuous current rating of a contact does ont indicate its ability to handle the high inrush currents of solenoids which may be three to eight times the normal current. Some contacts will weld together on inrush currents twice the continuous rating of the contacts. In general, large contacts having a greater mass and cooling area will usually handle larger inrush loads before welding together because of their greater thermal capacity.

Mounting and Installation: Proper installation of timers is essential to trouble-free service. A proper enclosure should be provided to keep the mechanism clean under conditions of service where it is to be used. Where the timing will require frequent changing, a timer with a dial outside the case should be used. Otherwise operators may leave the covers of the case open and the timer mechanism will be continuously exposed to accumulation of dust. Where timers are mounted in machines, they should be protected against the possibility of hydraulic fluids dripping into the mechanisms.

Standardization on 110-volt timer and control circuits is recommended. Many machine manufacturers have already standardized on 110-volt control circuits. Timers are specialized devices usually built to each customer's requirements so that they cannot be stocked by distributors and be readily obtainable for any voltage. Changing the motors and coils for a different voltage is not economically practical except in emergencies. By standardizing on one control voltage, manufacturers can stock timers built for their requirements and even stock complete control panels. Then using a machine control panel on a given line voltage only means making the proper transformer connections and installing proper size heater coils in the motor starters.

Locating timers in ambient temperatures above 120 F should be avoided. Higher temperatures tend to dry out the lubrication in the timer motors. Some types of motors can be relubricated by using a syringe to inject a small quantity of oil into the housing. The manufacturer should be consulted as to the type and amount of oil to use. For continuous operations at high temperatures, silicone oils can be used. It is necessary to have the motor built specially for silicone oil as this oil cannot be used in motors which have previously been lubricated with more commonly used petroleum oils.

Mounting timers on machines subject to severe vibration or shock should be avoided. The advantages of electrical control built into machines is important in some cases and timers have given years of satisfactory service on machines having a nominal amount of vibration from motors and pumps. Discretion should be used and mounting timers on equipment such as a mold vibrator should be avoided.

Where a control may involve several timers and other standard electrical control devices, the timer manufacturer can advantageously engineer and build the control system into one enclosure and furnish it to the purchaser as a single package. In this way, the responsibility of selecting the proper timer for the job rests with the manufacturer. Selection of the other standard components can then be based upon the needs of the timing circuits. This will bring appreciable savings in engineering, purchasing individual component parts, assembly, and testing.

"Each new development is increasing the need for automatic controls . . . instruments are being called upon to become the hearts and brains of America's accelerated demand for new, better and more products."—HENRY F. DEVER, *president, Brown Instruments Div., Minneapolis-Honeywell Regulator Co.*

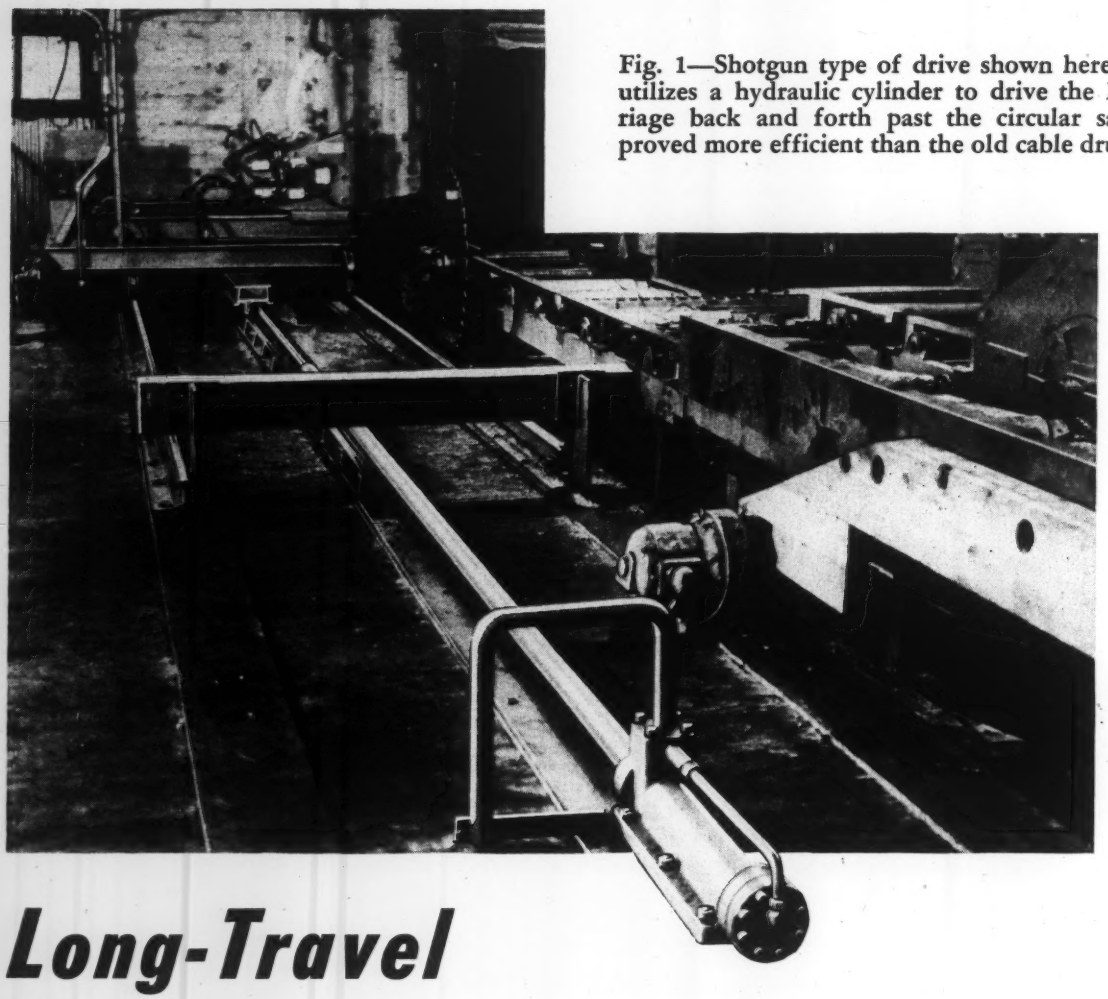


Fig. 1—Shotgun type of drive shown here, which utilizes a hydraulic cylinder to drive the log carriage back and forth past the circular saw, has proved more efficient than the old cable drum type

Long-Travel Hydraulic Drive

. . . utilized for high-speed sawmill carriage traverse

By Richard E. Davis *Engineering Representative, The Oilgear Co., Milwaukee, Wis.*

HEAVY sawmill carriages, because they operate at high speeds with short starting and stopping time allowances, place heavy demands on the type of drive used. Regulation of the carriage motion at high speed must be so precise a good operator can control the reversal point within fractions of an inch.

Briefly, the sawmill consists of a log carriage running on rails back and forth past a band or circular saw. The log can be moved in and out on the carriage to regulate the thickness of board to be cut. The carriage must be rugged enough to withstand the high-speed operation and the shock encountered when logs are loaded.

Carriage weights vary from less than 5000 to 100,000 pounds. For sawing logs 16 feet long, an average carriage will weigh from 10,000 to 25,000 pounds. Such carriages must often make 18-foot round trips in three seconds with top speeds reaching 1200 fpm.

There are a number of important characteristics desired in a carriage drive. Some of these are:

1. *Controllability.* This factor is of primary importance since the operator must be able to select a speed to suit each individual log. The size and condition of the log as well as the condition of the saw affect the speed of sawing. Control must be sufficiently precise to permit carriage reversal immediately after a board has been cut off
2. *Speed.* High speed is necessary for high production. The time required to return a carriage to position for a new cut is lost time and must be kept as short as possible. Boards are frequently cut from 16-foot logs at rates as high as fifteen per minute
3. *Cost.* As in all industrial equipment, cost is important. Besides first cost, power consumption and maintenance are important operating items.

Two general methods of driving sawmill carriages are in use: cable drive and cylinder drive. In a cable drive the carriage is pulled by cables from a rotating drum driven hydraulically. More recently developed is a type of carriage drive, *Fig.* 1, usually called a shotgun drive, in which hydraulic cylinders replace the oil motor, cable drum and reducer. Experience with these drives indicates they surpass the cable drum type in performance and control.

Safety Control

Compressed air actuates protective controls for a two-cycle gas engine

By M. C. Metzger

Assistant to Chief Engineer, Engine Division Worthington Pump and Machinery Corp. Buffalo, N. Y.

TO PROVIDE for safety in the operation of two-cycle scavenged gas engines, the integrated system of pneumatically actuated protective devices shown in *Fig.* 1 has been developed. This system which utilizes compressed air available for starting, prevents hazardous errors in starting procedure and employs automatic fuel shutoff to stop the engine when operation is unsafe.

Errors in starting procedure which may produce hazardous conditions are:

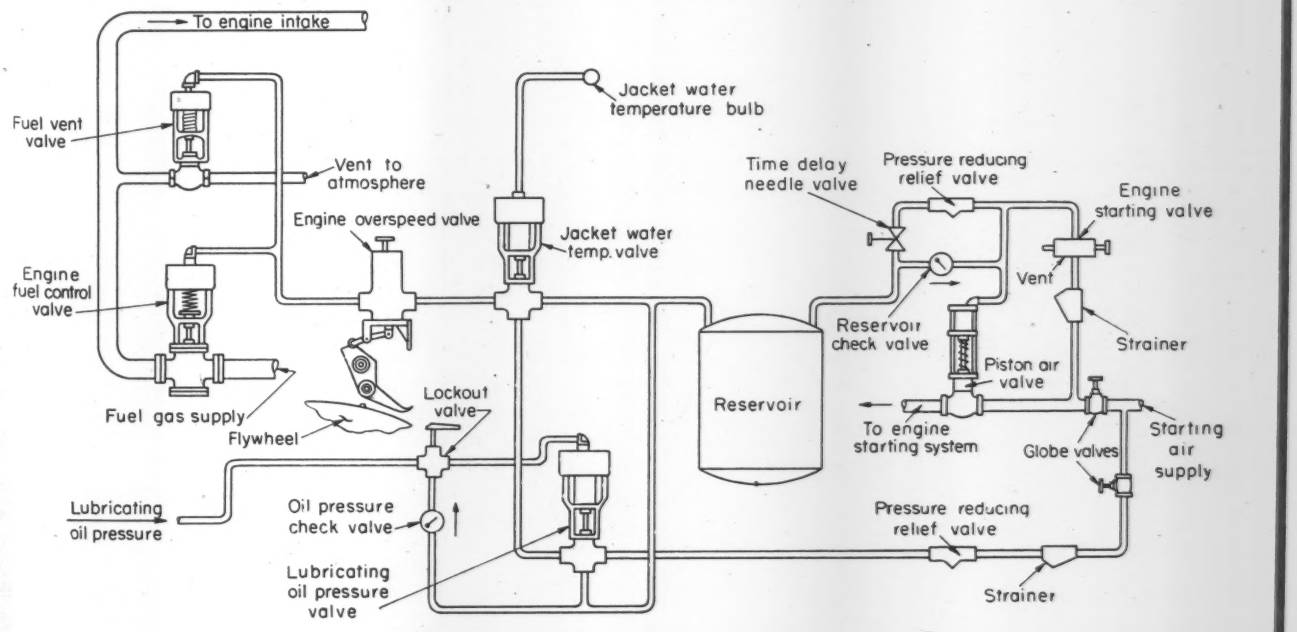
1. Admission of fuel to the engine before the ignition system is energized
2. Failure to purge the engine of combustible gases before the ignition system is energized
3. Failure to repeat purge operation if engine fails to start on initial attempt

After the engine has started, automatic fuel shutoff will occur when:

1. Lubricating oil pressure drops below safe operating limits
2. Jacket water temperature is excessive
3. Engine overspeeds
4. Fuel and lubricating oil pressure protective devices fail
5. Actuating air pressure falls below required system pressure.

In addition to the pneumatically actuated components, a protective ignition-throttle mechanical inter-

Fig. 1—Interlinked system of pneumatically actuated components which provides safe operation of a two-cycle gas engine



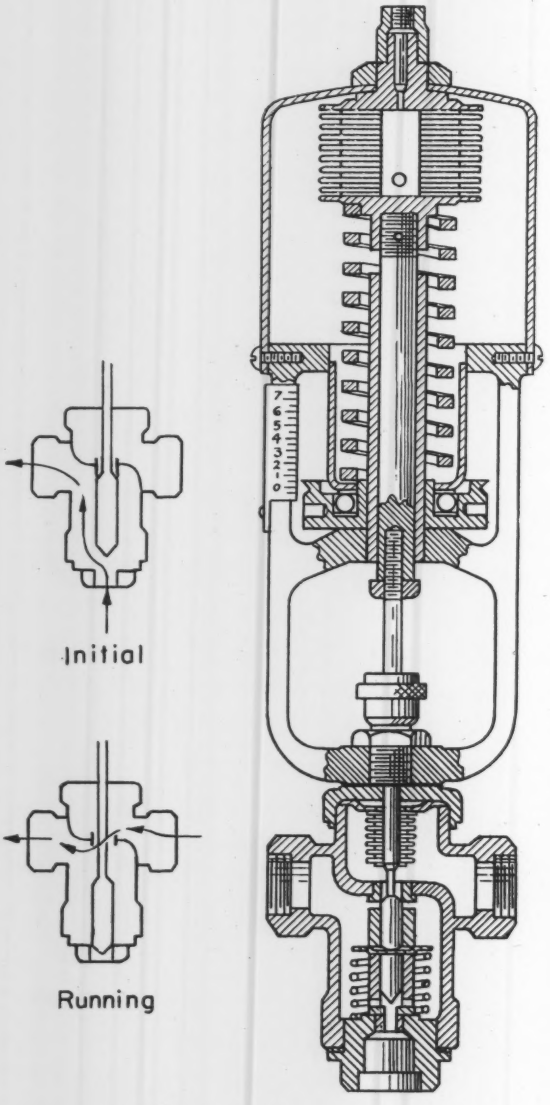
lock is provided. A spring-loaded collar on the ignition switch engages a notched quadrant on the fuel throttle. When the ignition switch is de-energized and the throttle is closed, the collar locks with the quadrant and the fuel throttle lever cannot be moved again until the ignition switch is energized.

A diagram of the pneumatically actuated system is shown in *Fig.* 1. Operation of the various components includes manual starting, automatic sequencing and automatic safety shutdown.

Starting: Preparation for starting is accomplished by manual operation of four valves:

1. Engine overspeed valve is placed in "run" position
2. The two manual globe valves in starting-air supply are opened
3. Oil pressure lockout valve is placed in "start" position.

Fig. 2—Detail of bellows-operated lubricating oil pressure valve. Sketches show valve in initial and running positions. Jacket water temperature valve is of similar design but remains normally in "initial" position unless jacket temperature becomes excessive



Opening the globe valves admits full air pressure to the inlet of the engine starting valve, the piston air valve, and reduced pressure to the lubricating oil pressure valve, which is shown in its initial position in *Fig.* 2.

The oil pressure lockout valve is a three-way two-port end-open valve. When placed in "start" position, it admits air pressure from reservoir to the pressure element of the lubricating oil pressure valve to simulate engine oil pressure. In the "run" position, oil pressure from the engine is applied directly to the lubricating oil pressure valve.

After the preparatory steps are completed, the hand knob of the engine starting valve, which has a spring return, is pulled out and held. Full air pressure is thus applied to the operating element of the piston air valve which opens the line to the engine starting system and allows compressed air to enter the engine. Timed injections to the power cylinders turn the engine.

At the same time, part of the air passing through the engine starting valve is delivered to the reservoir through a pressure-reducing valve and a time-delay needle valve. As pressure increases in the reservoir, the rate of buildup being determined by the needle valve setting in accordance with time required for engine purging, the increase is transmitted to the pressure element of the fuel-control valve and manifold vent valve through the lubricating oil pressure valve, the jacket water temperature valve and the engine overspeed valve. When correct pressures are attained the fuel vent valve closes and the engine fuel control valve opens. The fuel vent valve is adjusted to close when the pressure in the line is slightly under that required to open the fuel control valve. Both of these valves are of the two-way pneumatically operated type.

Pressure build-up in the reservoir is also transmitted to the pressure element of the lubricating oil pressure valve through the oil pressure check valve and the lockout valve. At the correct pressure, the lubricating oil valve assumes its running position, *Fig.* 2, the port connected to the reservoir being closed and air pressure being supplied directly from the starting air supply through the reducing valve. This transition is essential to provide a permanent supply of air to the automatic shutdown system of the engine while running.

Starting is now accomplished in the following manner:

1. While the engine is turning on air to insure complete purging of combustible gases, the ignition system is energized
2. The fuel throttle is gradually moved from "stop" to "run" position
3. When the engine fires, the hand knob of the engine starting valve is returned to its normal closed position
4. When minimum safe lubricating oil pressure is reached, the lockout valve is turned from the "start" to the "run" position.

(*Concluded on Page* 254)

Free-Piston Engine

. . . for air compression and turbine gas generation

DESIGN ABSTRACTS

By A. L. London and A. K. Oppenheim
Stanford University, Stanford, Calif.
University of California, Berkeley, Calif.

A FREE-PISTON machine is, essentially, an opposed-piston, crankless, two-stroke diesel engine driving a reciprocating air compressor. The reciprocating motion of the engine is transmitted directly to the compressor piston without the intermediary of two-crank systems as employed in the conventional combinations of internal-combustion engines and reciprocating compressors. The most notable features of the free-piston system are:

1. Constructional simplicity arising from the absence of cranks and associated bearings
2. Essentially vibration-free operation provided by the opposed-piston crankless design
3. Absence of piston - cylinder side thrust as introduced by crank and connecting rod systems

These advantages are gained with no sacrifice of thermodynamic performance within the cylinders and, in principle, with a substantial gain in mechanical efficiency as a result of fewer moving parts and lower loadings on the remaining bearing surfaces.

In the conventional crank engine, by virtue of the mechanical constraints imposed by the crank, engine speed and compression ratio are independent variables for the designer. This allows a complete separation of the thermodynamic and dynamic considerations. In most cases the only thermodynamics that the internal-combustion engine designer will use is a selection of mean effective pressure to establish the necessary piston displacement. The remainder of the design is established primarily from mechanical considerations. In contrast, for the free-piston system, the absence of the crank results in a "spring-mass" system which operates at a "natural frequency" established by the mass of the piston assemblies and the nature of the "gas springs" within the cylinders. Consequently the thermodynamic and dynamic considerations cannot be separated.

The free-piston system has three applications, *Fig.* 1:

a. Internal-combustion engine and air compressor combination; useful output is compressed air for pneumatic purposes
b. Air compressor and combustion chamber combination; production of hot gases under pressure for use in a turbine to derive shaft work
c. Compressed-air output of system *a* fed to a combustion chamber for heating prior to

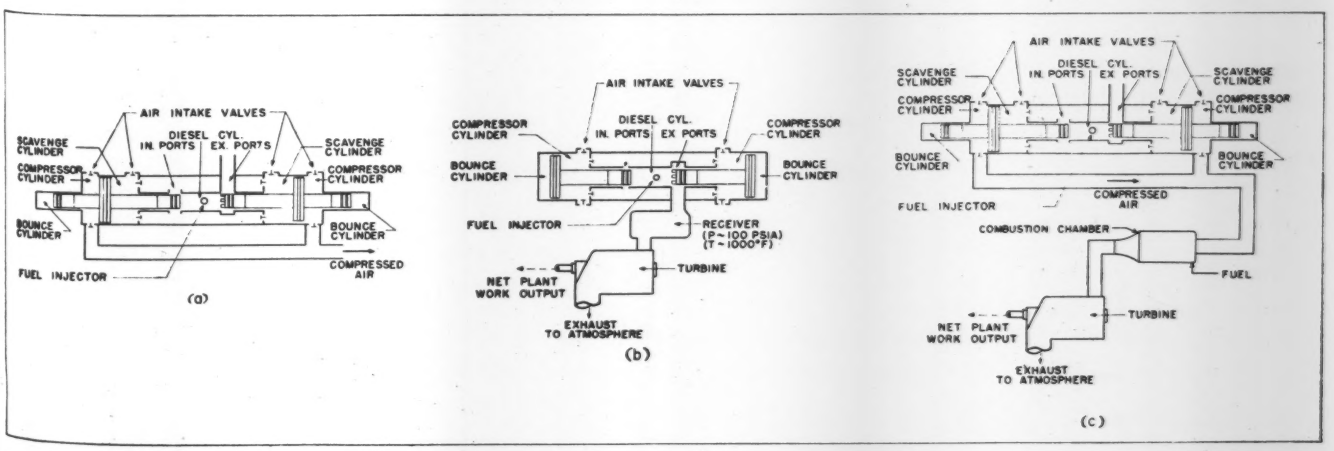


Fig. 1—Three basic applications of free-piston engines are *a,* air compression, *b,* power gas generation for a turbine drive, and *c,* hot air generation for a turbine drive

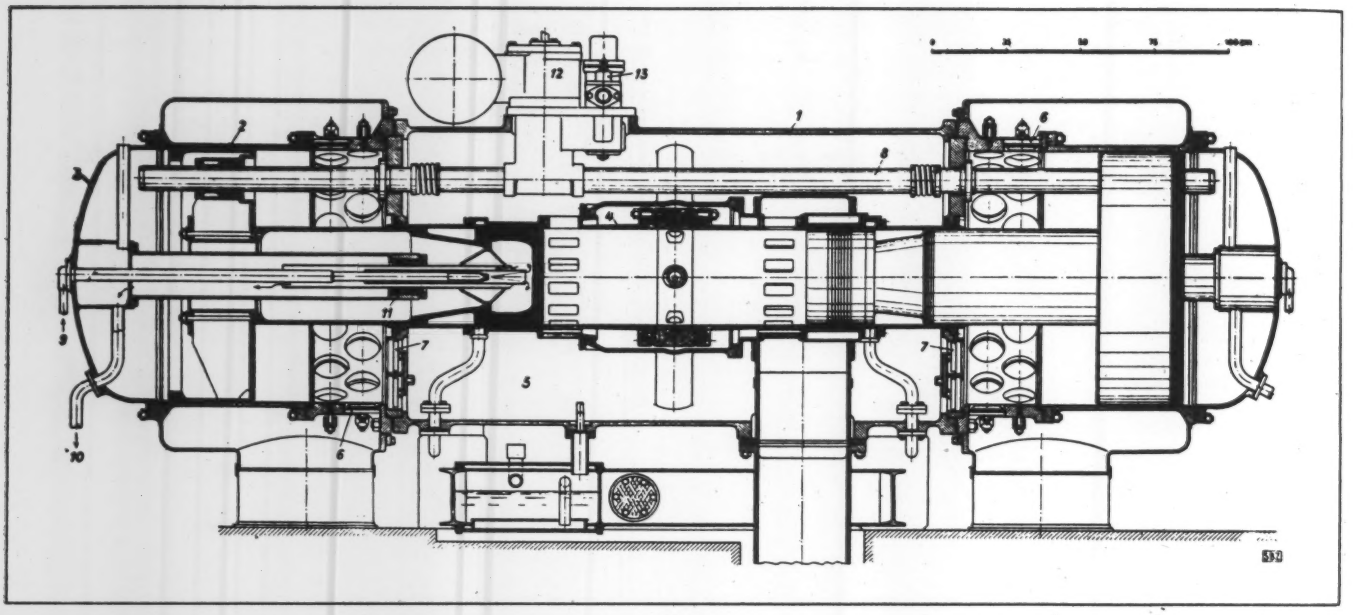


Fig. 2—Section drawing of a commercial 1000-hp free-piston gas generator of French make shows mechanical simplicity and compactness of the unit

use in a turbine to produce shaft work.

For supplying compressed air, the diesel engine section may operate with only a nominal supercharge pressure sufficient for scavenging in the two-stroke cycle. However, for power gas generation, the engine cylinder operates with a high supercharge—of the order of 3 to 6 atmospheres gage—derived from the compressor discharge, and exhausts at a high back pressure slightly less than the supercharge pressure.

The free-piston gas generator, like any highly supercharged engine, has very high heat-transfer rates per unit area at the cylinder walls. This condition results from combustion rates per unit cylinder volume being 4 to 6 times those of conventional diesel practice. Consequently, serious cylinder-wall lubrication and ring-wear problems are introduced. The free-piston air compressor involves no such heat transfer difficulties because with the nominal supercharge employed, combustion rates per unit cylinder volume are quite conventional. Moreover, the compressor has already been demonstrated convincingly as a military and commercial reality in Germany, France, and England. The Junkers organization provided free-piston compressors, as standard units, to the German Navy (submarines and destroyers) for torpedo-launching air.

A commercial 1000-hp free-piston gas generator is illustrated by the section drawing, *Fig.* 2. The functions of the cylinder spaces are as shown in *Fig.* 1*b*. Particularly noteworthy points of comparison relative to a 1000-hp heavy-duty crankshaft diesel are:

1. Mechanical simplicity arising from the comparatively small number of parts and, in particular, the absence of a crankshaft.
2. Compactness, small floor space requirement, and low weight.

A Junkers 4-stage free-piston compressor is shown in *Fig.* 3. Compressors of this type were standard equipment for both submarines and destroyers in the German Navy, where they were used to provide air compressed to 3000 psi for torpedo launching.

A single-cylinder opposed-piston diesel engine is located in the central section of this system. Both intake and exhaust valves are of the port type, located at opposite ends of the diesel cylinder to provide uniflow scavenging. The first and fourth compressor stages are located at the left-hand end of the unit, while the second and third-stages are at the other end. Water-cooled tubular intercoolers reduce the air temperature between compression stages, and also serve as air ducts between the stages.

The left-hand piston assembly consists of the diesel piston associated with the scavenge-port-end of the engine cylinder, together with the first and fourth-stage compressor pistons. The right-hand assembly consists of the exhaust-port-end diesel piston, together with the second and third-stage compressor pistons. Both assemblies are of identical mass, 65.4 $\pm$0.05 lb. The power pistons are connected solidly to the first and second-stage compressor pistons. However, the third and fourth-stage compressor pistons are secured by articulated joints. This allows for some misalignment of the cylinders.

Exactly opposed kinematic action of the pistons is essential for operation of the unit. Two pairs of synchronizing racks are tied to the piston assemblies for this purpose. Each pair, consisting of one rack from each piston assembly, acts on a 32-tooth pinion, about 3¾ inches in diameter. The pinion bearings in the casing are located at the central section diametrically opposite each other, with their axis normal to the longitudinal axis of the casing. One pinion shaft serves as a power take-off for the fuel pump. The second pinion, located diametrically opposite, provides a power take-off for the lubricator and coolant pump.

The semischematic section drawing, *Fig.* 4, shows the cylinder arrangement. The fourth-stage cyl-

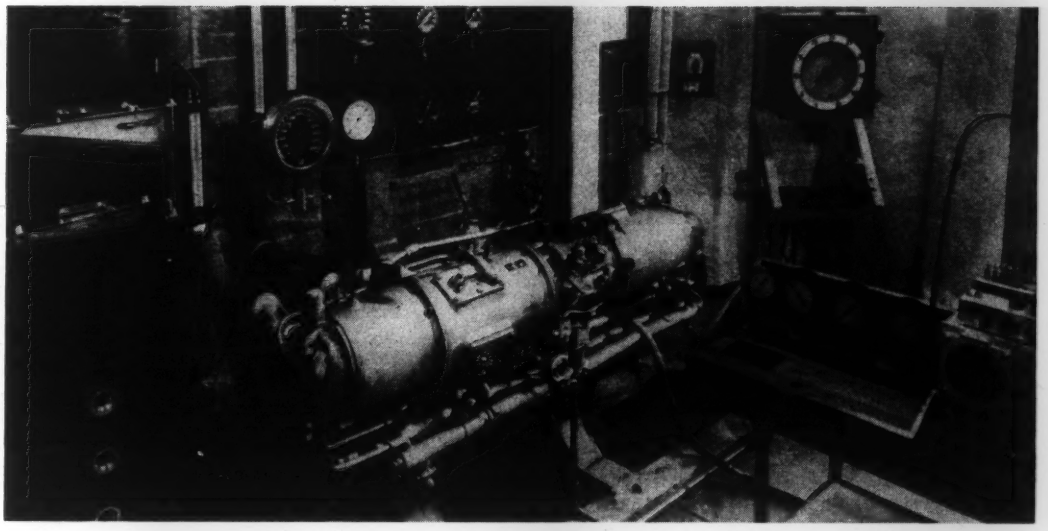


Fig. 3—Junkers 45-hp free-piston four-stage compressor unit was utilized by German Navy in World War II for submarine work

inder nests within the recess of the first-stage piston, and the third-stage cylinder is recessed within the second-stage piston. This arrangement substantially reduces the overall length of the unit. The diesel cylinder has a separate wet-liner. Intake ports at the left are arranged to induce a scavenge air swirl, thus improving charging by causing turbulence during fuel injection. This results in better combustion. The fuel injection nozzle is located in the cylinder wall at the center section.

The back face of the first-stage compressor piston serves as a scavenge pump supplying roughly 80 per cent of the engine air to the scavenge air space. The remaining 20 per cent of the engine air is furnished during the initial portion of the first-stage compressor stroke through a circumferential series of cylinder-wall valves located approximately 35 per cent of the stroke length up the cylinder.

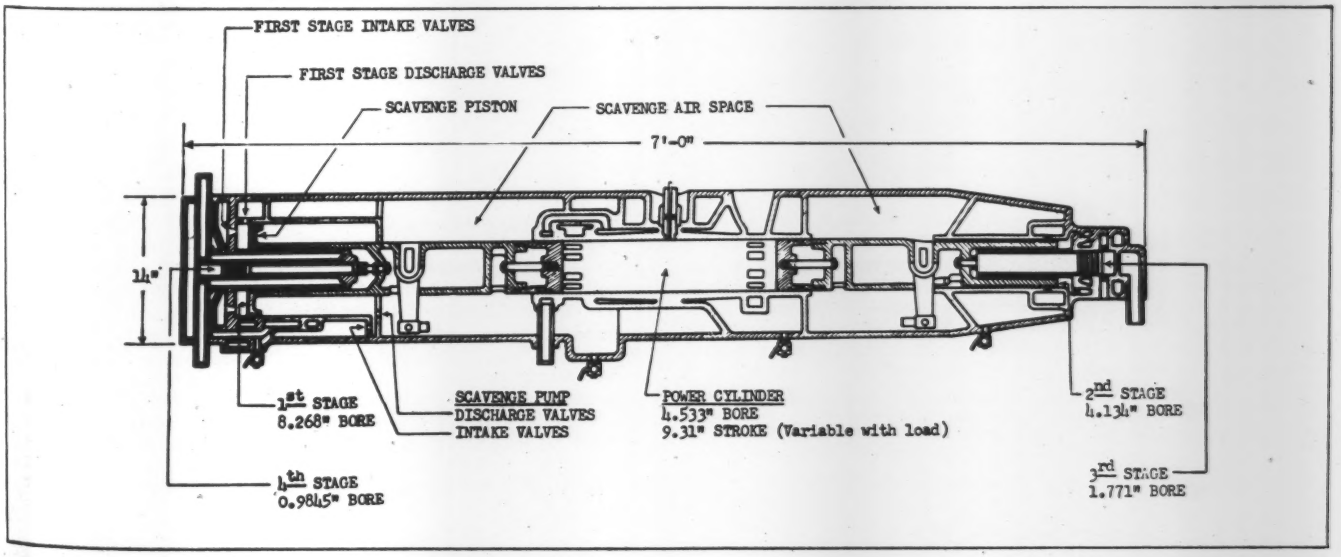
All compressor and scavenge-pump intake and discharge valves are 0.55 inches in diameter with spring - loaded pressure - actuated disks. Total flow is controlled by the number of valves in parallel.

Starting of the unit is accomplished by compressed air. Prior to starting, the piston assemblies are locked in outward position. Compressed air, supplied at 250 psig, is admitted manually to the first and second-stage cylinders through pressure regulator valves. When the cylinder pressures reach 175 psig in the second-stage and 60 psig in the first-stage, the lock is automatically tripped, the power pistons are "kicked" together with a volumetric compression ratio of about 40 to 1, and fuel is injected simultaneously. With this high compression ratio, ignition occurs unless malfuctioning of the fuel system prevents injection. A back pressure regulator on the after-cooler air discharge prevents delivery to the receiver until the back pressure on the fourth stage reaches 750 psig. This is necessary to insure sufficient clearance-air energy in the compressor cylinders to provide the return bounce for engine compression.

Compressor development, *Figs.* 1*a* and 1*c*, is substantially less difficult than the gas generator development, *Fig.* 1*b*, because of the absence of high engine supercharge. Nevertheless the thermo-

(*Continued on Page* 272)

Fig. 4 — Section drawing of unit in *Fig.* 3 shows cylinder arrangement which delivers 70.5 cfm (free air) at 2950 psi



NEW PARTS

AND MATERIALS

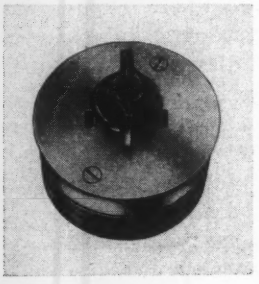
. . . presented in quick-reference data sheet form for the convenience of the reader. For additional information on these new developments, see Page 229

TIMING SWITCH 1

. . . provides two independent circuits

M. H. Rhodes Inc., 30 *Bartholomew Ave., Hartford, Conn.*

Particularly useful on clothes driers or similar units, this switch provides a cooling period between shut-off of heater elements and shut-off of blower.



Designation: 6701-T.

Size: $2\frac{11}{16}$ in. diam, $1\frac{25}{32}$ in. high.

Service: Underwriters Laboratories approved for operation at 28 amp, 250 v ac (1 hp load); adjustable time interval; two independent circuits, which can be arranged to provide a predetermined time interval between breaking of one circuit and breaking of second.

Design: Spring-driven; splashproof and dustproof housing.

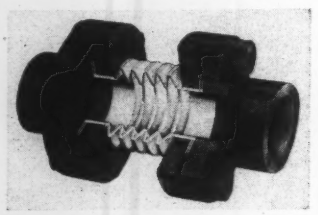
For more data circle MD 1, Page 229

BELLOWS CONNECTOR 2

. . . fabricated of chemically inert plastic

Crane Packing Co., Dept. G27, 1800 *Cuyler Ave., Chicago, Ill.*

Electrolysis and vibration are eliminated by this expansion joint.



Size: For 1 to 8-in. pipe; specials available.

Service: Connecting pipe lines carrying corrosive liquids or gases, or solvents; electrically nonconductive, eliminating electrolysis; damps vibrations; flexible to −94 F; full strength from 70 to 480 F; leakproof seal.

Design: Chemically inert Teflon bellows, with from 1 to 20 convolutions; French-type envelope gaskets integral with joint for assembly between companion flanges.

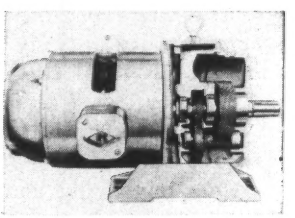
For more data circle MD 2, Page 229

MOTOR-REDUCER 3

. . . with internal fluid coupling

Reuland Electric Co., 3001 *W. Mission Rd., Alhambra, Calif.*

Integral fluid coupling provides cushioned starting of heavy loads and smooth acceleration.



Size: ½ to 15 hp.

Service: Output speeds from 1 to 600 rpm; smooth starting and acceleration; protects equipment against jamming or shock loading.

Design: Single or double reduction gearing from single or polyphase motor; helical gears, hobbed from special alloy steels, operate in an oil bath, assuring positive lubrication; dripproof or totally enclosed designs available.

Application: Cranes, conveyors, dryers, mixers, car pullers.

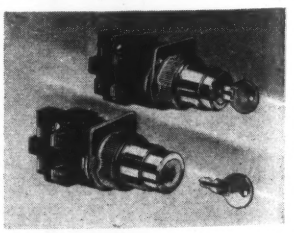
For more data circle MD 3, Page 229

KEY-OPERATED SWITCHES 4

. . . available as selector or pushbutton

Westinghouse Electric Corp., Box 2099, *Pittsburgh* 30, *Pa.*

Switches can be mounted on panels varying from $\frac{1}{16}$ to ¼-in. thick without an extra gasket.



Designation: 15-022.

Size: $2\frac{1}{16}$ in. behind panel, $1\frac{3}{8}$ in. diam mounting hole; selector—$1\frac{5}{8}$ in. front of panel, pushbutton—$1\frac{11}{16}$ in. front of panel, both less panel thickness.

Service: Key locking of electric circuits to prevent tampering with circuit; oiltight; panel, surface or flush mounting.

Design: Single or double-pole; selector has choice of 2 or 3 positions, with key removal in any one or all positions; pushbutton can be depressed in either full or intermediate positions with key removal in both depressed and undepressed position, or either one.

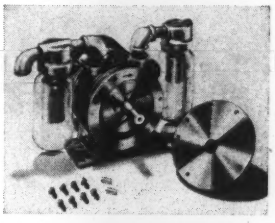
For more data circle MD 4, Page 229

NEW PARTS AND MATERIALS

AIR PUMPS 5

. . . deliver oil-free air

Gast Mfg. Corp., Benton Harbor, Mich.



Vanes are made of carbon, eliminating metal-to-metal contact and necessity for oiling.

Designation: 0740, 1550, 3040.

Size: 0740—6¼ in. long x 3¾ in. wide (approx) x 4 1/16 in. high; 1550—8 5/16 x 6 5/16 x 6⅝; 3040—11 1/16 x 7⅝ (approx) x 8⅜.

Service: Producing up to 20 in. vacuum, 10 psi pressure; 0740 delivers 3.5 to 5.6 cfm, 1550 from 8 to 10.5 cfm, 3040 from 17 to 24 cfm; no hot oil vapor or mist is delivered with air; oil maintenance eliminated; vanes are self-adjusting for wear; pumping characteristics are unaffected by temperature changes.

Design: Rotary vane type; four carbon vanes are self-lubricating; ball bearings, grease-sealed for life; grease cannot enter pumping chamber.

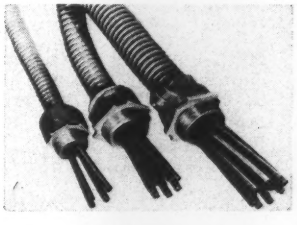
Application: Paper and food-handling machinery; instruments and controls.

For more data circle MD 5, Page 229

ARMORED CABLE 6

. . . carries 4 to 12 fluid control circuits

Bailey Meter Co., 1050 *Ivanhoe Rd., Cleveland* 10, *O.*



Hydraulic or pneumatic control lines are protected by this flexible steel-spiral cable.

Designation: Armortube.

Size: ¼-in. OD tubes; random lengths, approx 500 ft;

Tubes	Cable OD (in.)	Bending Radius (in.)	Weight — Aluminum (lb/ft)	Weight — Copper (lb/ft)	Thread Fitting (in., IPS)
4	0.85	6	0.5	0.7	1
8	1.08	7	0.7	1.1	1¼
12	1.32	9	0.85	1.45	1¼

Service: Protected hydraulic and pneumatic transmission lines; transmits hydraulic pressures to 3000 psi, all ranges of pneumatic control pressures; connections and takeoffs may be made in standard electrical junction boxes; tracer tube identifies tube ends, since all tubes in bundle maintain same relation.

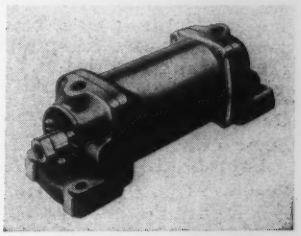
Design: Aluminum or copper tubes are gathered in a slow, continuous spiral, then wrapped in water-repellent insulating tape; rust-resistant galvanized steel strip is wound similar to BX electrical cable.

For more data circle MD 6, Page 229

DOUBLE-ACTING CYLINDERS 7

. . . designed without tie rods

Rivett Lathe & Grinder Inc., Brighton 35, *Boston, Mass.*



Keeper-ring construction eliminates tie rods and allows end covers to be rotated to match ports to pipe locations.

Size: Bore diam, 1½, 2, 2½, 3, 4½, 6, 8, 10 or 12 in. except center-line mounted model, which is supplied in 3, 4½, 6 or 8 in. diam only; strokes to 96 in.

Service: Maximum air pressure, 150 psi, oil pressure, 300 psi; ample rod bearing area; self-adjusting composition packing provides sealing effect proportional to cylinder pressure; since tie rods are eliminated, cylinder can be applied in minimum of space.

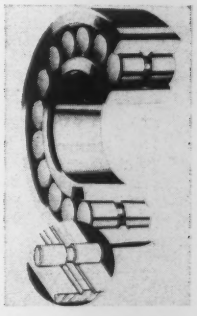
Design: Double-acting; clevis, rabbet, center-line, foot, blind-end flange, rod-end flange or trunnion mountings; single or double-end rods except blind-end flange or clevis mountings; internal or external rod threading; alloy covers are bored to fit a turned diameter on tube (cylinder) wall; alloy piston rod and covers; cushioned cylinders on rod or blind end available; specials available.

For more data circle MD 7, Page 229

GUIDED-ROLLER BEARINGS 8

. . . have high load-bearing capacity

McGill Mfg. Co., Valparaiso, Ind.



Alignment of the roller at right angles to direction of travel is maintained by the guide rail.

Designation: Guiderol.

Size: 0.375 to 8 in. shaft diam, 1.125 to 11.125 in. OD, 0.750 to 3 in. width; without inner ring, same except 0.625 to 9.250 in. shaft diam.

Service: Load capacity is high, since rollers make contact to outside edge of races, and elimination of cages allows full complement of rollers; increased axial rigidity because of increased lengths of rollers; may be mounted in any position; open-end construction allows lubricant to flush or clean the bearing.

Design: Grooved rollers kept in alignment at right angles to direction of travel by guide rail; should roller attempt to skew, leading end of roller contacts rail and is retarded, allowing trailing end to catch up; retaining ring on inner race helps maintain alignment; two models available, one with outer race, rollers and separable inner race, the other with outer race and rollers only.

For more data circle MD 8, Page 229

NEW PARTS AND MATERIALS

FLEXIBLE MICA 9

. . . available as sheet, tape or laminate

General Electric Co., Chemical Div., Pittsfield, Mass.

Manufactured by a new process, this insulating material consists of small mica flakes bonded to form a continuous sheet.

Designation: Mica Mat.

Size: Continuous sheet from 0.002 to 0.006-in. thick; impregnated tape, 0.0085-in. thick, 20 yd roll.

Service: Class H electric insulation; dielectric strength comparable or better than machine and hand-laid mica; properties of Mica Mat and glass cloth bonded with silicone resin as follows—70 psi tensile strength, good flexibility, 750 v per mil dielectric strength (ASTM D144-49, short time), 0.025 power factor (60 cycle at 25 and 100 C) and 0.027 (125 C); can be molded or machine wrapped when impregnated.

Design: Continuous mica sheet; available impregnated with resins and bonded to paper, glass or cloth as sheet, tapes or laminates.

Application: Heating devices, motors, generators.

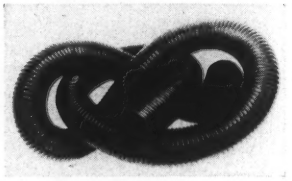
For more data circle MD 9, Page 229

LIGHTWEIGHT HOSE 11

. . . of wire-reinforced neoprene and nylon

American Ventilating Hose Co., 100 *Park Ave., New York* 17, *N. Y.*

Exceptional strength and resistance to abrasion are claimed for this flexible hose.



Size: 1½ to 24 in. ID; weight, 0.24 to 7 lb per ft, respectively.

Service: Pressure, vacuum or conveying; good flexibility and wear resistance; test applications show good service in heavily abrasive conditions and under constant flexing; can be used for gravity feeds.

Design: Nylon chafer duck laminated with neoprene compounds.

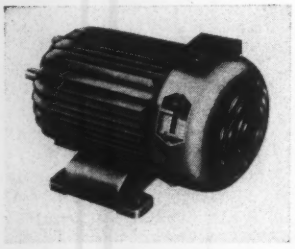
For more data circle MD 11, Page 229

TOTALLY ENCLOSED MOTORS 10

. . . stress compact design and low weight

Hoover Co., Kingston-Conley Div., 68 *Brook Ave., North Plainfield, N. J.*

Intermediate sizes are fan cooled, and large sizes have external fins for greater heat dissipation.



Size and Service: General-purpose where dust, dirt, wood chips or metal shavings are encountered; precision-balanced rotors for low vibration; external lubrication; capacitor start motors for 115/230 v, except 3 hp for 230 v only; polyphase motors for 208/220/440 v;

Rating (hp)	Speed (rpm)	Frame (NEMA)	Rating (hp)	Speed (rpm)	Frame (NEMA)
¼	1140	66	1	1140*	204*
	1725	56		1725	203
	3450	56		3450	66
⅓	1140	66	1½	1140*	224*
	1725	56		1725	204§
	3450	56		3450	203
½	1140	66	2	1725	224§
	1725	56*, 66†		3450	204
	3450	56*, 66†	3	1725*	225*
¾	1140	204§, 203*		3450	224
	1725	66	*Polyphase only. †Capacitor start only. §Capacitor start and run only.		
	3450	66			

Design: Totally enclosed, fan cooled from ¾-hp up, plus all capacitor-start 1140-rpm models and ½ hp, 1140 rpm model in polyphase; blind passages eliminated on fan-cooled models; removable fan shroud; Formvar-insulated windings.

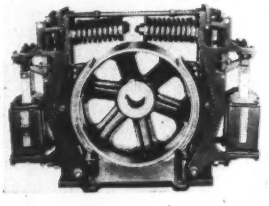
For more data circle MD 10, Page 229

SOLENOID BRAKE 12

. . . consists of two separate operating units

Trombetta Solenoid Corp., 329 *N. Milwaukee St., Milwaukee* 2, *Wis.*

High capacity of the solenoids allows these brakes to be used for actually stopping rotation, not merely for holding.



Size: Capacities to 24,000 lb-ft, continuous duty.

Service: Shoe brakes are operated by long-stroke solenoids, with 40-50% of stroke required to release brake, 50-60% available to take up lining wear, thus extending periods between adjustments; 2 anti-toeing devices on each shoe eliminate toeing problems; brakes adjustable for wear at top and bottom; fine torque adjustment on springs from 0 to full value; brake can be aligned after mounting; available for (1) release by ac solenoid, holding in released position by ac current, (2) ac operation, dc holding, (3) dc operation, dc holding; shunt or series operation on dc.

Design: Brake consists of four sets of double springs and 2 solenoids for release of 2 independent shoe operating units (connected by a torque tie bolt); each unit capable of releasing brake by itself so that one unit may be used as a spare; hand release provided; 2 shock absorbers, one for each end of stroke, are provided on each solenoid.

For more data circle MD 12, Page 229

Conformability

THE tolerance of adjustment to loading or misalignment is known as conformability. If a bearing could be kept in perfect alignment with the shaft it supports and if an oil film could be maintained at all times, there would be no need for more than one bearing material. This ideal bearing material would be hard so that it would resist changes in load that would be expected in normal machine operations, whether these be starting loads, firing loads or loads due to work of the machine.

Actually it is well known that perfect alignment is seldom attained. Tolerances alone, if they are all in an unfavorable direction, can add up to slight misalignment. The tolerance in location of a hole, plus the tolerance of the bore, plus the tolerance of the bearing wall, plus the tolerance of the shaft, presents a difficult problem for the design engineer.

Part of the problem is solved by selection of a proper bearing material. Advantage is taken of a different kind of tolerance—a tolerance of the bearing material to move and adjust itself to unfavorable loading or to slight misalignment.

Conformability is also very important if the oil film is broken and perfect lubrication is lost for a short period. As soon as the oil film is broken the local bearing area starts to heat and local dimensions change. If the material is conformable it will move to better support the load. Then when the oil film is reestablished the bearing will run cooler than before. These are some of the changes that take place during break-in and explain why a bearing will change and even show signs of distress in the first few hours of running and yet run many hundreds and even thousands of hours with little change after break-in.

In general, soft materials conform so that conformability is an inverse function of hardness and is thus best in the babbitts. Unfortunately if a material is too soft, it will move under high loads and the properties of conformability must come to a compromise with the properties of load carrying capacity and fatigue resistance which are associated more with hard materials than soft materials. A compromise for this situation is to use a thin layer of a soft babbitt on a harder backing such as bronze or steel. Then the harder backing will carry the load while the thin babbitt will furnish desirable bearing properties and yet carry higher loads due to its thinness.

For higher loads bronze on steel is used. Conformability is sacrificed at the expense of gain in load carrying capacity with the necessity of design for more ideal conditions for bearing operation.

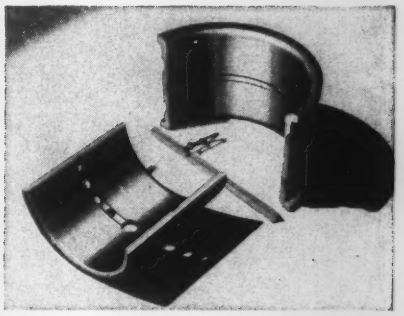
In the use of steel backed bearings, conformability is lost because the steel has less ability to conform compared to the bearing materials used at the running surface. If the lining material is soft it will conform, but if it must be thin conformability is limited.

Relative Comparison of Conformability

Relative properties of bearings based on wide bearing experience showing relative conformability and tolerance to scoring at expense of low fatigue resistance and low load carrying capacity. The relative position of a bearing material will change from this generalization with the composition of the alloy, for instance the amount of lead in a leaded bronze. It will also change remarkably with the thickness of babbitt on a backing material.

SOFT MATERIALS
High Conformability
Low Tendency to Score
Low Load
Low Fatigue Life

HARD MATERIALS
Low Conformability
High Tendency to Score
High Load
High Fatigue Life



Babbitt lined bronze is an ideal combination for both load carrying capacity and conformability.

If a bearing such as solid bronze is subject to a deforming load, the bronze will move, not only at the bearing surface but at the back. The whole bearing will move. The surface will conform to the new shaft position, the back will seat itself more properly and the bearing as a whole will assume a proper running position.

A bearing cannot be selected on the basis of one desirable property. If very high loads are required fatigue resistance and load carrying capacity take precedent. If corrosive conditions are encountered the selection of alloys is limited. The proper bearing material must be selected to best fit the operating conditions.

Engineering Service

Johnson Bronze offers manufacturers of all types of equipment a complete engineering and metallurgical service. We can help you determine the exact type of bearing that will give you the greatest amount of service for the longest period of time. We can show you how to design your bearings so that they can be produced in the most economical manner. As we manufacture all types of Sleeve Bearings, we base all of our recommendations on facts free from prejudice. Why not take full advantage of this free service?

This bearing sheet data is but one of a series. You can get the complete set by writing to—

Johnson Bronze

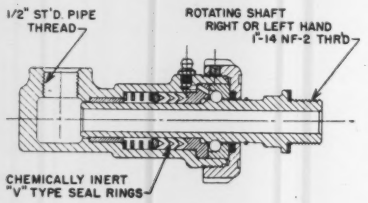
SLEEVE BEARING HEADQUARTERS
525 S. MILL ST. • NEW CASTLE, PENNA.

NEW PARTS AND MATERIALS

REVOLVING JOINT 13

. . . for high-speed rotating equipment

Barco Mfg. Co., Dept. J-8, 1801 Winnemac Ave., Chicago 40, Ill.



Featuring inert chevron seal rings with a low coefficient of friction, this joint is adaptable to rotating clutches, chucks and similar equipment.

Designation: IBRSA.

Size: $6\frac{9}{16}$ in. long; 1-14 NF-2 machine threads (right or left hand) for rotating connection; ½-in. pipe thread for stationary end.

Service: Connecting air or hydraulic lines to parts rotating at speeds to 1800 rpm, or more under certain conditions; suitable for temperatures to 425 F; seal rings have a low coefficient of friction and have little tendency toward scoring.

Design: Right-angle; chemically inert chevron seal rings; connection to stationary end by pipe or hose, with hose recommended for free-floating installation.

For more data circle MD 13, Page 229

PRESSURE REGULATOR 15

. . . for exact control of small-volume air flow

C. A. Norgren Co., 3442 S. Elati St., Englewood, Colo.

Especially suited for use with air-controlled instruments, this regulator is claimed to give precise control in a low-cost unit.

Designation: 11, 400-2, -2G, -2GG.

Size: Flange diam, 3¼ in.; height, center of port to top, 6¼ in.; ¼-in. pipe-thread ports; two ⅛ or ¼-in. NPTF gage ports on -2G and -2GG models.

Service: Pressure control of air, nitrogen or inert gas in 0 to 30 psi delivery range at 0 to 2 cfm; operates on line pressures to 400 psi; can be adapted for delivery pressures to 50 psi with special spring; built-in relief feature prevents excessive pressure; valve seat, ball and diaphragm are corrosion resistant.

Design: Nylon relief-valve seat and regulator-valve ball; nylon-reinforced synthetic-rubber diaphragm; dry-seal pipe threads; model 11, 400-2G has 2 ports for gage, -2GG supplied with gage; easily disassembled without removing from line.

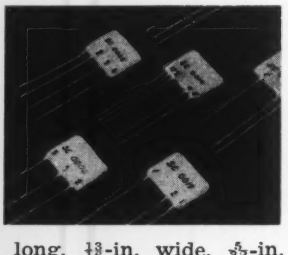
For more data circle MD 15, Page 229

PRINTED ELECTRIC CIRCUITS 14

. . . with built-in resistors and capacitors

Stupakoff Ceramic & Mfg. Co., Latrobe, Pa.

As many as six circuit elements can be incorporated into these compact units.



Size: Approximately 1⅛ in. long, $\frac{13}{16}$-in. wide, $\frac{5}{32}$-in. thick, or smaller; 1¾ in. leads.

Service: Complete resistor and capacitor electrical circuit for connecting into electrical or electronic assembly; standard circuits include integrator and interstage coupling circuits, specials available; 2 to 6 separate components can be replaced by one assembly; reduction of 25-80% in number of soldered connections, depending on circuit; protected from abrasion and humidity.

Design: Patterns for conductors, capacitors and resistors are printed on vitreous, high-dielectric ceramic plates by a silk-screen process; silver is used for conductors and capacitors, with the ceramic dielectric separating capacitor poles; carbon-graphite or other resistance material is used for resistors; patterns are bonded on ceramic by controlled curing, then protected by impervious plastic covering.

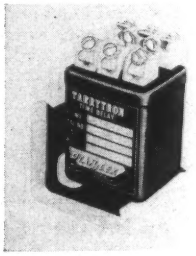
For more data circle MD 14, Page 229

TIME DELAY RELAY 16

. . . is accurate over wide temperature range

Cook Electric Co., 2700 N. Southport Ave., Chicago 14, Ill.

A high degree of repeatability is maintained over a 230 F range.



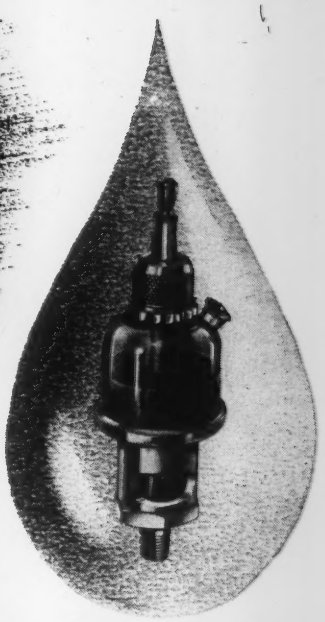
Size: $1\frac{9}{16}$ in. wide, $1\frac{13}{16}$ in. long, 2⅛ in. high without terminals; weight 8½ oz max.

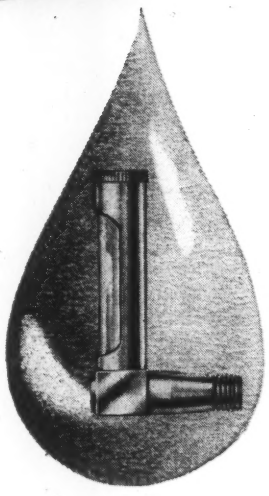
Service: Factory-adjusted time delay of 2 to 15 sec between operation of control circuit and operation of relay circuit; repeatability, ±9% from −65 to +165 F; hermetically sealed and filled with dry nitrogen for high-altitude operation; no resonance or failure between 0 and 200 cps vibration at 5*g* (prolonged); withstands standard 10*g* vibration at 10-55 cps and 25*g* shock test as outlined in MIL-R-6106; 5 amp resistive, and 3 amp inductive or motor load at 28 v dc and 115 v ac; heater consumption, 11 w; holding relay consumption, 4 w.

Design: Double-pole, double-throw contacts; screw-type compression terminals of molded nylon with permanently stamped red lettering on white background; universal mounting bracket is spot welded and copper brazed to container; heater operates during time-delay portion of operation only.

For more data circle MD 16, Page 229

For Lubricating Devices Call On GITS First!





GITS Bros. covers the *entire range* of lubricating devices: Oil Hole Covers, Oil Cups, Grease Cups, Bottle Oilers, Gauges. Gravity-Feed, Wick-Feed, Constant Level, Vibrating Rod styles. Threaded or Drive-type. Elbow or Straight.

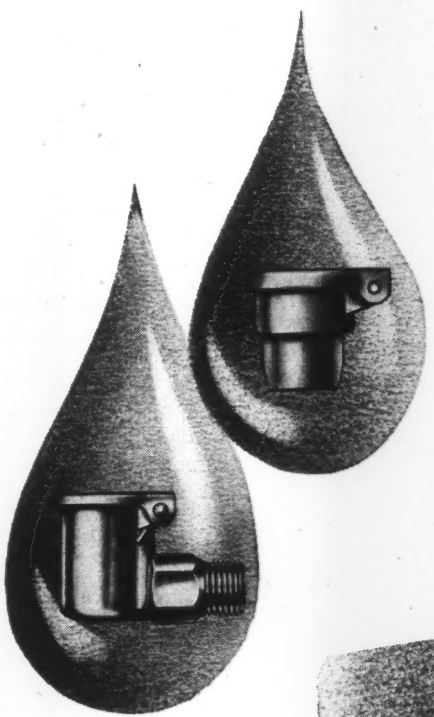
GITS Bros. offers the most complete selection of standard styles.

GITS consistent quality in design, materials and machining has made Gits Lubricating Devices the standard for industry for more than 40 years.

GITS Lubricating Devices are far-famed for solving tough oiling problems at low cost.

GITS Bros. Engineering Staff—true specialists in lubrication engineering—is at your disposal.

Write today for free Catalog No. 60-A. Use it as your handy reference for lubricating devices.



GITS BROS. MFG. CO.

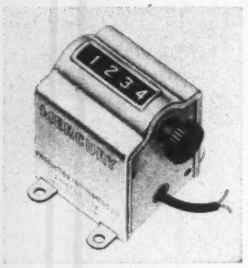
1868 S. KILBOURN AVE. • CHICAGO 23, ILL.

NEW PARTS AND MATERIALS

FOUR-DIGIT COUNTER 17

. . . registers electric impulses at high rate

Production Instrument Co., 702-08 *W. Jackson Blvd., Chicago* 6, *Ill.*



Small and compact, this counter may be actuated by a switch, relay or photoelectric unit.

Size: $1\frac{23}{32}$ in. long, $1\frac{9}{16}$ in. wide, $2\frac{13}{16}$ in. high.

Service: Registers electric impulses at speeds to 600 per min; for 6, 12, 24, 48 or 115 v, dc or 60-cycle ac; all number wheels are reset to zero by one turn of reset knob.

Design: Four-digit reset; enclosed in metal case with plastic window; foot-mounted, or with brackets for panel mounting.

For more data circle MD 17, Page 229

GLASS-BRAID TUBING 19

. . . coated with silicone rubber

Irvington Varnish & Insulator Co., 6 *Argyle Terrace, Irvington* 11, *N. J.*

Performance requirements of government specification MIL-I-3190 for Class H electric insulation are met by this coated glass sleeving.

Designation: Grades H-A-1, H-B-1, H-C-1, H-C-2.

Size: Size No. 24 and 20 through 0 in lengths to 36 in.

Service: Withstands 200 C temperature for 200 hr without embrittlement; retains flexibility from −60 to +180 C; 5 to 10% water absorption after 24-hr immersion, mostly on surface of glass fibers; resistance to chemicals and abrasion is limited; minimum average voltage breakdown as follows:

Temperature	Grade			
	H-A-1	H-B-1	H-C-1	H-C-2
(C)	(v, rms)	(v, rms)	(v, rms)	(v, rms)
25	7000	4000	2500	1500
100	6800	3800	2475	1475
200	6500	3500	2400	1400

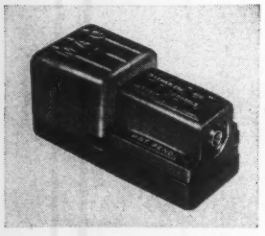
Design: Selected sizes of glass braid are coated by special multiple-coat process with silicone rubber.

For more data circle MD 19, Page 229

SOLENOID VALVE 18

. . . controls double-acting air cylinders

Mechanical Air Controls Sales Co., 15311 *W.* 11 *Mile Rd., Royal Oak, Mich.*



Operation is by direct solenoid control and spring return of the spool, which is the only moving part.

Designation: 501.

Size: Ports for ¼-in. pipe; 5 in. long, 2½ in. wide, 2½ in. high.

Service: Actuating double-acting pneumatic cylinders; O-ring seals are only wearing parts; gland-type packing not required; spool is easily accessible; current, 0.8-amp inrush, 0.2-amp holding at 115 v, 60 cycles others available; mounted in any position; exhaust port may be restricted for reduced cylinder piston speeds.

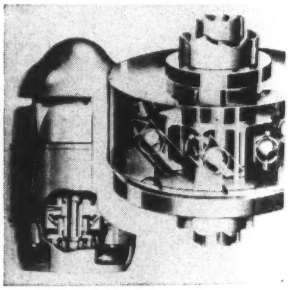
Design: Four way; constant-duty solenoid controls aluminum spool for operation, with return of spool by spring; two O-ring seals, mounted on spool, slide on honed, polished, hard-chrome plated and repolished bore; full ¼-in. pipe orifice area through valve; cast-iron base; bronze body and retainers; aluminum solenoid covers; side base pipe porting is standard, with bottom porting or manifold mounting available; end-cap retainers are held on body by retaining rings, easily removed.

For more data circle MD 18, Page 229

VERTICAL MOTORS 20

. . . with steel-ball backstops

U. S. Electrical Motors Inc., 200 *E. Slauson Ave., Los Angeles* 54, *Calif.*



Steel balls are wedged between a rotating cage and a fixed ratchet to prevent backspin of these motors when connected to vertical pumps.

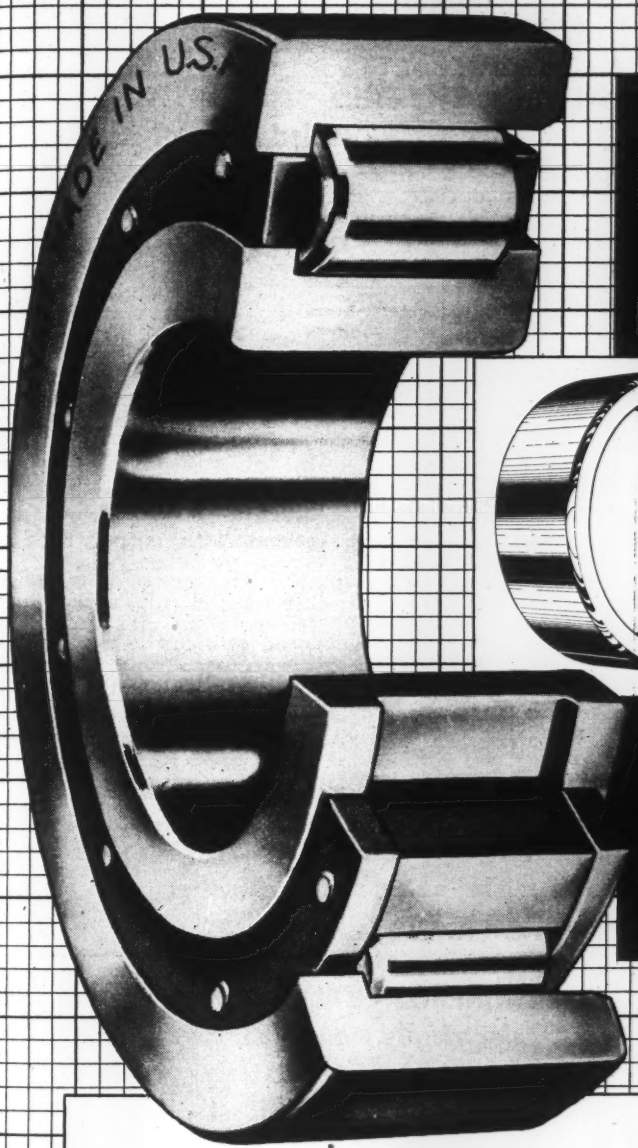
Designation: Ballomatic.

Size: 1½, 2, 3, 5, 7½, 10, 15, 20, 25, 30 and 40 hp motors.

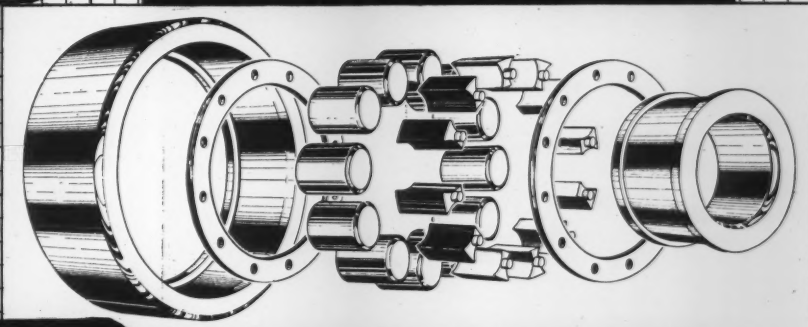
Service: Counterclockwise rotation, viewed from top of motor; backstop stops backspin in 1/63 revolution or less, preventing excessive shaft speeds, vibration or damage to pump bearings when motor is connected to high-head turbine pump; available for 208, 220, 440, or 550 v, 25 or 60 cycles, 2 or 3-phase—or 115 or 230 v, 60 cycles, single-phase.

Design: Vertical hollow shaft with integral backstop; when motor starts, centrifugal force throws hardened steel balls out of engagement with stationary ratchet; when motor stops, gravity and inertia of balls causes one of them to engage between a ratchet flute and the rotating outer cage; a differing number of balls and flutes are used, multiplying the locking combinations and thus reducing impact.

For more data circle MD 20, Page 229



Versatile Radial Bearings



HYATT HY-LOADS

The BU-L type of Hyatt Hy-Load is a two part roller bearing having a single flanged, separable outer race. Rollers are retained by a conforming bar cage and flanges at both ends of the inner race.

Race flange and roller end squareness, uniformity of roller dimensions and smooth operating surfaces are construction details that assure quiet, smooth, long-lasting performance at high speeds—capacity for carrying heavy loads.

The flanged races permit the BU-L Hy-Load Bearing to locate the shaft endwise and to carry an intermittent thrust load. In pairs, they can locate the shaft in both directions or accommodate light thrust from either direction.

You can take advantage of these and other features of the Hyatt line of radial roller bearings in the equipment you are designing or building. Look to your Hyatt Catalog or write for further information to Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey.

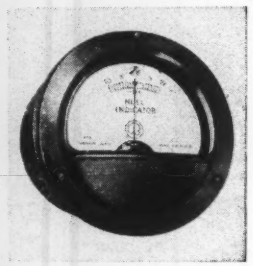
HYATT ROLLER BEARINGS

NEW PARTS AND MATERIALS

NULL INDICATOR 21

. . . sealed and ruggedized

Marion Electrical Instrument Co., Manchester, N. H.



Use of this new instrument will permit precise measurement under field conditions previously considered prohibitively severe, the company claims.

Designation: HS2, HS3.

Size: HS2—2½ in. diam; HS3—3½ in. diam; mounting requirements and dimensions in accordance with JAN-1-6.

Service: Null indication with high center-point sensitivity of 1 micro-amp per mm or higher; sharply logarithmic attenuation upon departure from null point, giving ample overload protection up to 10 times actual rated full scale value.

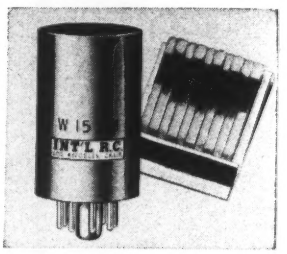
Design: Alnico V magnet with shaded pole faces; shielded soft-iron core; available with numerous current sensitivity and internal resistance characteristics.

For more data circle MD 21, Page 229

SELENIUM RECTIFIERS 23

. . . hermetically sealed in metal cases

International Rectifier Corp., 1521 *E. Grand Ave., El Segundo, Calif.*



Standard tube terminals to fit standard sockets provide for quick replacement.

Size: $1\frac{5}{16}$ in. diam; height depends on rating, with unit shown being $2\frac{15}{16}$ in. overall.

Service: Rectifying ac current with output ratings from 1.5 to 120 ma; various circuits available, including half-wave, full-wave and bridge; unit illustrated is full-wave center-tap circuit with rated output of 140 v dc at 120 ma from maximum rms input of 390 v center tapped at 195 v—also has 550 v peak inverse rating; protected against corrosive atmospheres, moisture, salt spray and fungus.

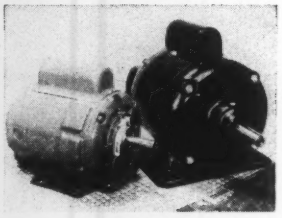
Design: Circuits are hermetically sealed in metal cans and filled with inert gas or oil.

For more data circle MD 23, Page 229

FRACTIONAL-HP MOTORS 22

. . . redesigned for light weight, smaller size

General Electric Co., Fractional Horsepower Motor Dept., Schenectady 5, *N. Y.*



In addition to weight and size reduction, these motors (left) have been restyled to present a streamlined, modern appearance.

Designation: Form G, type K, KC, KH, KCP.

Size: K, KC—1/6, ¼, ⅓, ½, ¾, 1 hp; KH—1/12, 1/6, ¼, ⅓ hp; KCP—1/12, ⅛, 1/6, ¼, ⅓, ½, ¾ hp.

Service: K (polyphase)—constant speed for standard applications; KC (capacitor start)—high starting torque under heavily loaded conditions; KH (split phase)—moderate starting torque and smooth performance; KCP (permanent split capacitor)—quiet, multispeed operation under constant load; weigh as much as 51% less per hp than older models; all-angle operation.

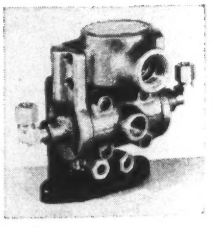
Design: Welded steel base and shell hold motor in alignment in any mounting position; sleeve bearings permit moderate thrust loads; double-end ventilation with cast-in ventilating fins and grids; nylon material for slot and between-phase insulation; Formex insulated wire; red Glyptal varnish baked on stator; split-phase motors have glass-insulated wire; open dripproof or totally enclosed fan-cooled models.

For more data circle MD 22, Page 229

EXPLOSIONPROOF VALVE 24

. . . electrically controlled but air powered

Bellows Co., 230 *W. Market St., Akron* 9, *O.*



A tiny sealed solenoid acts merely as a trigger to release air against the floating piston which actually operates the slide valve.

Designation: EVX-5A, -10A, -15B.

Size:

Model	Ports (pipe, in.)	Width* (in.)	Depth (in.)	Height (in.)
EVX-5A	¼-18	$3\frac{31}{32}$	3⅞	$4\frac{13}{32}$
EVX-10A	⅜-18	$4\frac{1}{32}$	4	$4\frac{13}{32}$
EVX-15B	½-14	$4\frac{13}{32}$	4¼	$5\frac{11}{32}$

* Without poppet exhaust ports

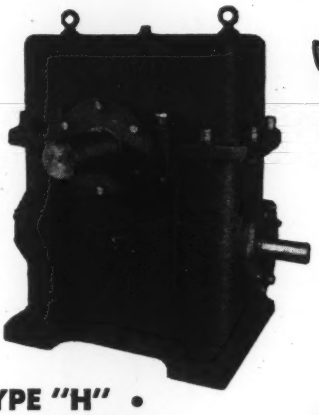
Service: Electric control of air cylinders in Class I, Group D (explosive vapor) atmospheres; solenoids can operate at speeds as high as 2200 movements per min without hum, pounding or overheating; solenoids are guaranteed against burnout providing valve is connected in accordance with diagram; operates on 8 v from batteries or Bellows transformer, which can be connected to 110, 220, or 440 v, 60 cycles current.

Design: Four-way; plungers of sealed solenoids move only $\frac{1}{32}$-in. to direct air against floating piston which operates slide valve; valve will not operate unless air supply is connected; 2 speed-control regulators provide independent speed regulation of advance and retract strokes; cast bronze end caps; air motors available with valve integrally mounted.

For more data circle MD 24, Page 229

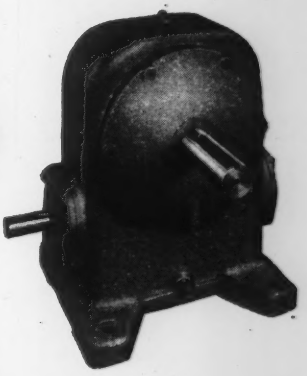
D.O.James

ESTABLISHED • 1888



TYPE "H" •

Horizontal or Vertical Drive— Each drive type comes in 15 sizes, with ratio ranges of 5.6:1 to 100:1 and from .06 to 206 horsepower.



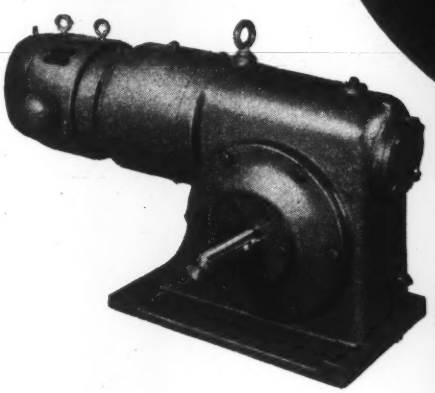
TYPE "S" •

Horizontal or Vertical Drive— Each type available in 8 sizes, ratio range of 5.66:1 to 100»1 and from .04 to 15.6 horsepower.

WORM GEARS AND WORM GEAR REDUCERS

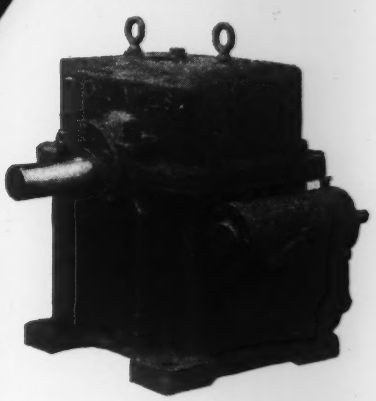
MOTORIZED •

Horizontal or Vertical Drive— Each drive type comes in 11 sizes, has ratio range of 5.6:1 to 100:1, with ⅛ to 30 horsepower, driven speeds of 310 r.p.m. to 17.4 r.p.m. Vertical drive slow speed shaft extends either upward or downward.



DOUBLE •

Horizontal or Vertical Drive— Each drive type available in 13 sizes, ratio range of 130:1 to 10000 and from .004 to 59.7 horsepower. Vertical drive slow speed shaft extends either upward or downward.

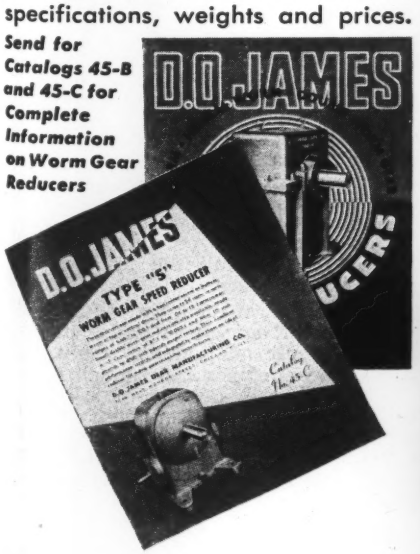


WORM GEARS

Generated on tangential feed hobbing machines by tapered and ground hobs. Made from 1" to 100" in diameter and from 24 DP to 1 DP.

Catalogs are available to users of Gears and Gear Reducers—containing valuable engineering data, specifications, weights and prices.

Send for Catalogs 45-B and 45-C for Complete Information on Worm Gear Reducers



D. O. JAMES Worm Gears and Worm Gear Reducers are designed and manufactured to have maximum inbuilt strength and to assure dependable *on-the-job* performance. The many and repeated installations of these reducers testify to their operating superiority and adaptability.

D.O.James GEAR MANUFACTURING COMPANY

1140 WEST MONROE STREET • CHICAGO, ILLINOIS

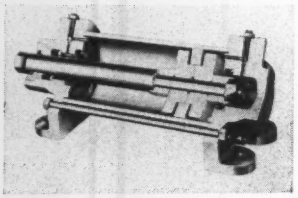
SINCE 1888—MAKERS OF ALL TYPES OF GEARS AND GEAR SPEED REDUCERS

NEW PARTS AND MATERIALS

PNEUMATIC CYLINDER 25

. . . has positive cushioning but fast return

Tomkins-Johnson Co., Jackson, Mich.



Flexible sealing elements provide cushioning action and automatic valving for a fast return stroke.

Designation: Super Cushion.

Size: 100 to 12,000 lb capacities.

Service: Maximum air pressure, 100 psi; cushioning at both ends of stroke controlled by adjustment valves; cushion sealing element automatically compensates for wear, eliminates binding or sticking; 2 flexible bronze rings mounted in synthetic rubber wipe dirt and grit off piston rod; metal male adapter ring gives support to chevron type packing, extending life of packing; large rod bearing area.

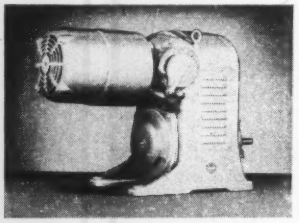
Design: Double action; flexible cushion sealing element is sealed by air pressure on forward stroke and opens to allow fast piston return stroke; available in foot, clevis, rod-end or blind-end flange, trunnion, face-plate, or centerline mounting; double-end rod types available; hard chrome plated rod and bore; O-ring static seal; seamless steel tube is precision honed.

For more data circle MD 25, Page 229

VARIABLE-SPEED DRIVES 26

. . . with integral explosionproof motors

U. S. Electrical Motors Inc., 200 *E. Slauson Ave., Los Angeles* 54, *Calif.*



Motor, speed-changing mechanism and gear reducer (if necessary) are all mounted on a single base.

Size: 1, 1½, 2, 3, 5, 7½, 10, 15 or 20 hp.

Service: Speed control in Class I Group D (flammable vapors), Class 2 Group F and G (combustible dust) atmospheres; available in 2:1, 3:1, 4:1, 5:1 or maximum (according to design) range of speed variation, infinitely adjustable; output speeds range from 1.4 to 3670 rpm, or to 10,000 rpm, special; motors are for 208, 220/440 or 550 v, 2 or 3-phase, 60-cycle current, are rated at 55 C.

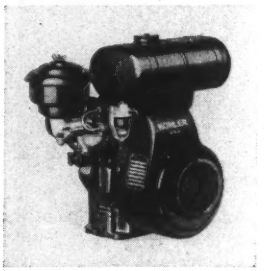
Design: Totally enclosed motor, with single or double enclosures, has V-belt and variable-pitch sheave speed-changing mechanism; enclosed unit is cooled from exterior by sparkproof fan; mechanical or electrical remote controls available.

For more data circle MD 26, Page 229

GASOLINE ENGINE 27

. . . compact, portable and lightweight

Kohler Co., Kohler, Wis.



This new lightweight engine has mounting dimensions comparable to present engines.

Designation: K90.

Size and Service: Rated 3.6 hp at 3600 rpm; weight, 44 lb.

Design: One-cylinder, four-cycle; ball bearings at both ends of crankshaft; dustproof and moistureproof breaker points are externally mounted for accessibility; ignition system operates from high-voltage crankshaft magneto; fly-ball governor; glass sediment bowl with fuel shut-off valve, rotating screen, muffler, and oil-bath cleaner; available variations include K90P, built for direct mounting with a threaded crankshaft, and K90R, which is equipped with 6:1 reduction gearing.

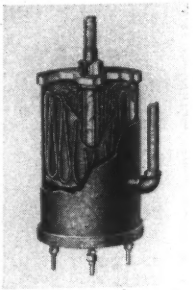
Application: Portable saws, mowers, centrifugal pumps.

For more data circle MD 27, Page 229

AIR CLEANER 28

. . . combines a filter, dehydrator and trap

Hankison Corp., 298 *Renton Bldg.,* 1501 *Beaver Ave., Pittsburgh* 33, *Pa.*



Water and oil are removed from the cleaner by an automatic trap.

Designation: B-30 Condensifilter.

Size: 9 in. diam, 15 in. high.

Service: Removing entrained or vaporized water and oil, sludge, scale and dirt from compressed air lines; capacity, 30 cfm at 100 psi with less than 2 psi pressure drop; operates on up to 500 psi pressure; removes dirt particles as small as 1 to 2 microns in size; filter normally needs cleaning only twice a year; for larger capacity or uninterrupted service, several units can be connected in parallel; requires ¾ to 1 gpm cooling water.

Design: Combination condenser, mechanical filter and self-purging trap; condenser consists of 22 ft of ⅜-in. copper tubing around a brass baffle, presenting over 300 sq in. of cooling surface, and reducing air temperature to within 2 or 3 deg F of cooling-water temperature; mechanical filter consists of 5 hexagonal filter chambers, each wrapped with 7 layers of canton flannel; self-purging trap is float operated with a snap-action, spring-operated valve.

For more data circle MD 28, Page 229

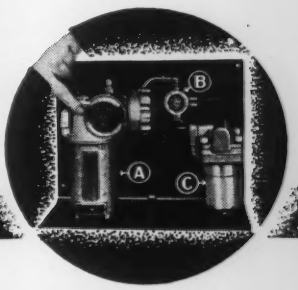
Fights Friction!... with new efficiency...
...new simplicity...new savings!

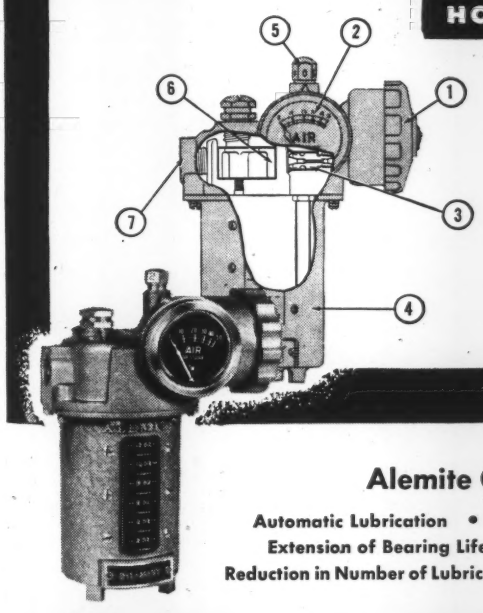
ALEMITE OIL-MIST LUBRICATION

Greatly extends bearing life!
Air pressure seals bearings! . . . Stops oil drippage!

WHAT IT IS: Alemite Oil-Mist is a completely automatic system of airborne lubrication for machinery application. It is an amazingly simple lubricator which applies a clean, constant, uniform oil film to groups of bearings designed for either oil or grease lubrication.

A unique lubrication system. Oil-Mist operates on compressed air—the lubrication unit has no moving parts. A basic system consists of (a) Lubricator, (b) Solenoid Control, (c) Water Separator, and bearing fittings and tubing.





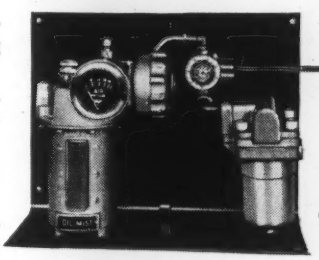
HOW IT WORKS: **The Oil-Mist Lubricator atomizes oil into microscopic particles which are carried in the air stream and distributed through tubing to bearings.**

Oil-Mist airborne lubrication is accomplished this way: Compressed air entering the unit passes through air regulator **(1)** and air gauge **(2)**. As this air passes through venturi **(3)** it draws oil from reservoir **(4)**. Oil flow is set by knob **(5)**. The mixture of air and oil from the venturi is thrust against baffle **(6)**. Only the most minute, lighter than air particles are blown through outlet **(7)** into delivery line to lubricate bearings.

Alemite Oil-Mist offers all these lubrication advantages

Automatic Lubrication • Continuous Lubrication • Eliminates Guesswork • Consumption of Oil Cut 90%
Extension of Bearing Life • Stops Oil Drippage • Reduction of Bearing Temperatures • Greater Safety
Reduction in Number of Lubricants • Protection from Contamination • Elimination of "Down-Time" • Manpower Savings

LUBRICATOR SPECIFICATIONS:



- Oil-Mist outlet ½" fem. p.t. Air gauge registers to 50 psi. Operating air pressure—5 to 20 psi.
- Air regulator reduces from pressures up to 200 psi. Normal air consumption—.7 to 1.2 cfm.
- Range of oils handled—to 1,000 sec. (S.U.V.) @ 100°F.
- Oil reservoir capacity 12 oz. (approximately 1 week supply). Intake filter screen—70 mesh. Fill plug—9/16".
- Material—die cast aluminum body with nylon plastic window.
- Baffle-type water separator—automatic self-dumping. Requires no manual attention—no filter elements to replace. Air inlet ¼" fem. p.t.

delivers oil to bearings *3ways*

1. Oil-Mist as Such. Most commonly applied to any type of anti-friction bearing—ball, roller or needle.

2. Oil in Spray Form. For open and enclosed gears and chains. Spray nozzle partially condenses mist into semi-liquid form and directs the spray onto a concentrated area.

3. Oil in Liquid Form. For plain bearings, slides, ways, vees, cams and rollers. In these applications, condensing fittings are used.

A PRODUCT OF SW STEWART WARNER

Alemite OIL-MIST Lubrication

Just out! This new Oil-Mist Catalog and Engineering Data Book. Write now for your FREE copy. Alemite, Dept. R-42, 1850 Diversey Parkway, Chicago 14, Illinois.

ENGINEERING DEPARTMENT

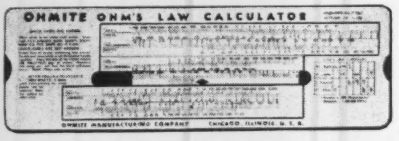
EQUIPMENT

For additional information on this new equipment, see Page 229

OHM'S LAW CALCULATOR 29

. . . now available in durable plastic

Ohmite Mfg. Co., 4937 W. Flournoy St., Chicago 44, Ill.



Two models are now available, the original model in varnished cardboard at a lower price, the new calculator in dimensionally stable plastic.

Size: 9 in. long, 3 in. wide.

Service: Three scales are included—(1) for computing Ohm's law problems with one scale setting and no computation of decimal points, (2) for computing parallel resistance problems in one setting, (3) for standard slide rule calculations with A, B, C and D scales; Ohm's law scale covers range of currents, voltages and wattages commonly found in industrial and radio work.

Design: Fabricated of durable, dimensionally stable Vinylite plastic; scale (1) on front of calculator, (2) and (3) on back.

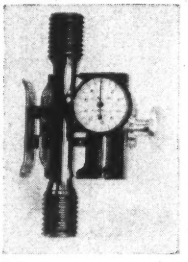
For more data circle MD 29, Page 229

EXTENSOMETER 31

. . . indicates elongation directly on scales

National Forge & Ordnance Co., Testing Machine Div., Irvine, Warren County, Pa.

No multiplying lever is used in this instrument.



Size: Gage length, 2 in.; specials with 1.4 in. gage length; weight, 7 oz.

Service: For tension testing; registers elongation to 0.045-in. on metal or plastic wire, sheet, plate or rounds to ½-in. thick or wide; dial divisions, 0.0002-in., allowing readings to 0.0001-in.

Design: Gaging element attaches to specimen by spring clamps, which are opened or closed by hand pressure; jewel-bearing indicator.

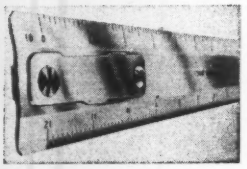
For more data circle MD 31, Page 229

DRAFTING MACHINE SCALES 30

. . . ground from solid aluminum flats

Universal Drafting Machine Corp., 7960 Lorain Ave., Cleveland, O.

A new anodized finish prevents glare under any type of lighting.



Designation: Duraline.

Size: 6, 12, 18 and 24 in. long.

Service: Scales available in 12 types of graduations most used by mechanical, electrical and civil engineers, draftsmen and architects; chucks fit any standard drafting machine; smooth ruling edge; graduations do not extend to drawing edge, eliminating "file" action on pencil point and resulting graphite smears; finish eliminates glare, prevents metal from smudging drawing paper even after long use.

Design: Stable aluminum-alloy scales are ground from aluminum flats, then engine-divided at 70 F to produce accurate graduations; graduations are filled with black, then scale is anodized to produce dull light-gray finish.

For more data circle MD 30, Page 229

TACHOMETERS 32

. . . accurate to 0.25 per cent of speed rating

Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

Accuracy is maintained by calibration adjustments mounted on the front of the instrument.

Designation: 42H, 42K, 42J; 46A or 46B adapters.

Size: 5⅜ in. wide, 8⅞ in. high, $4\frac{23}{32}$ in. panel depth required.

Service: Rotating speed measurement with accuracy of 0.25% of measured speed; operates on 115 v ac; 46A adapter multiplies speed by 0.1, 46B by 10.0;

Type	Range (rpm)	Torque (in.-oz) No adapter	46A	46B
42H	900-10,000	1/20	1	1/30
42K	360-4000	1/12	1 1/2	1/30
42J	90-1000	1/8	....	1/30

Design: Bridge circuit spreads out scale; 2 precision resistors provide reference standards for calibration and adjustment; 10 overlapping or adjoining ranges with rotary selector switch; hand-engagement head with 6-ft electric cable, two 60-deg cone tips; hollow cone tip and tip extension.

Application: Aircraft engine, turbine overspeed, production motor testing; dynamometer test stands.

For more data circle MD 32, Page 229

Contact KAYDON Muskegon

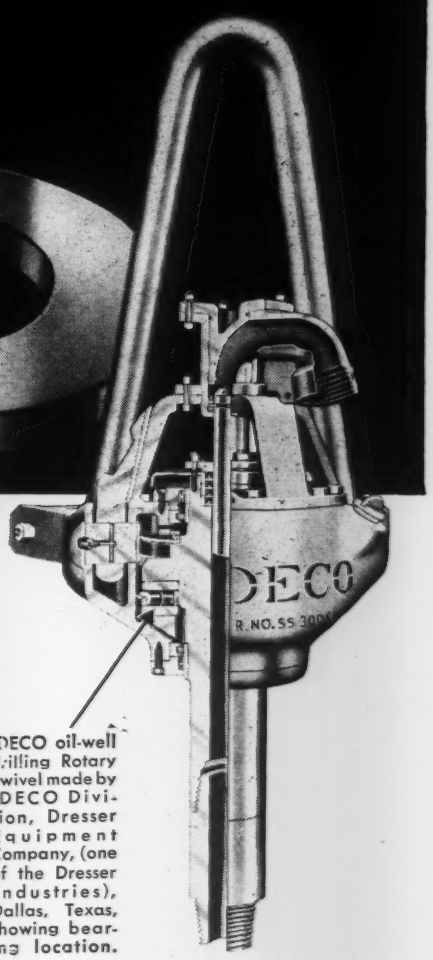
FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER

KAYDON Roller Thrust Bearings
10.630" x 18.976" x 4.725"
used in Ideco SS-300 Swivels

Takes 300-ton loads!

Dead-load capacities to 300 tons have been obtained, without added weight, in IDECO Streamlined Swivels for deep oil-well drilling. The success of these rotary swivels is the result of advanced engineering and years of experience in swivel manufacture. Rugged bearings are vital . . . husky **KAYDON** heavy-duty roller thrust bearings carry the full load.

In many other industries, machine designers find **KAYDON** bearings help make bigger machines possible, without unnecessary bulk and weight. If you have a bearing problem, contact **KAYDON** of Muskegon.



IDECO oil-well drilling Rotary Swivel made by IDECO Division, Dresser Equipment Company, (one of the Dresser Industries), Dallas, Texas, showing bearing location.

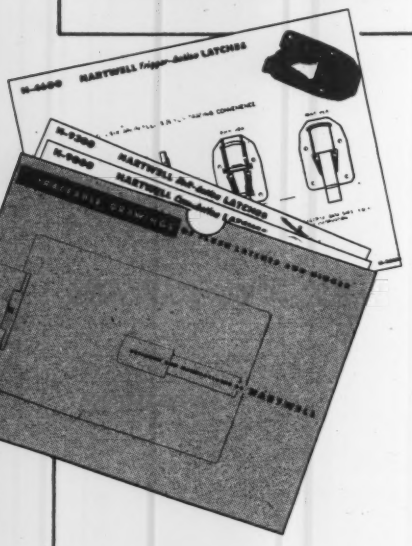
THE KAYDON ENGINEERING CORP.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust
• Roller Radial • Roller Thrust • Bi-Angular Bearings

MUSKEGON • MICHIGAN

PRECISION BALL AND ROLLER BEARINGS

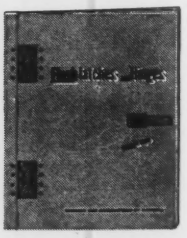
TRACEABLE DRAWINGS



...OF Flush Latches AND Hinges

another HARTWELL SERVICE

Specially prepared full size traceable drawings of all HARTWELL Flush Latches and Hinges are now available to designers and draftsmen. Request a complete file. They will be sent to you free of charge and without obligation. The HARTWELL policy of serving the needs of engineers and the industry includes the design and production of a complete line of flush latches and hinges for every application.



Write for new Flush Latch and Hinge Catalog

HARTWELL COMPANY

9035 Venice Boulevard, Los Angeles 34, Calif.
Branch Office: Wichita, Kansas

MEN OF MACHINES

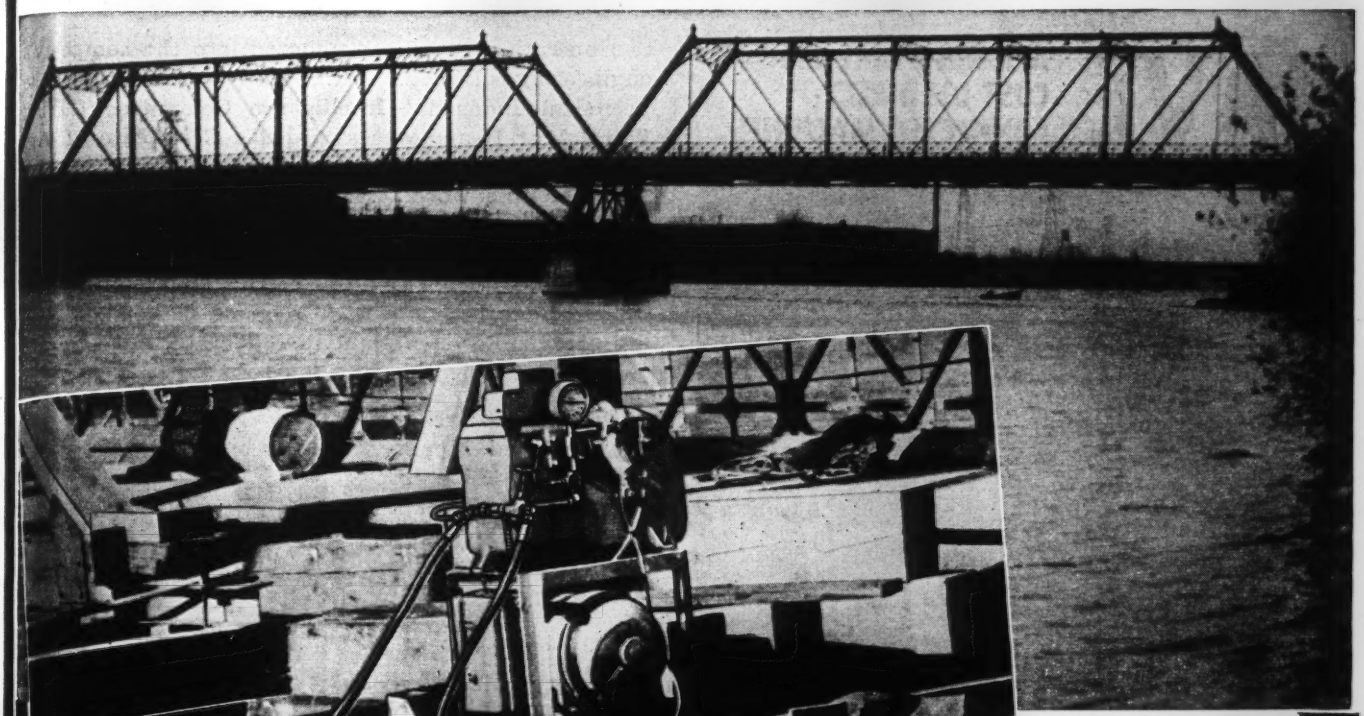
Ralph E. Price

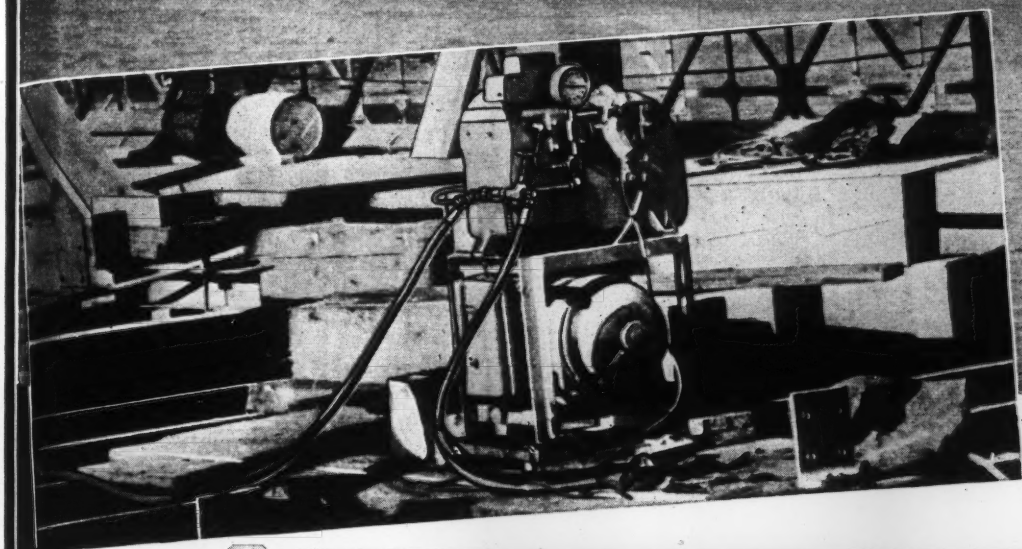
Ralph E. Price has been appointed assistant general manager of the Gardner Machine Co., Beloit, Wis. He began his career in the machine tool industry in 1929 at Landis Tool Co., progressed through successive stages of drafting and machine design, and was appointed to the position of chief designer in 1941. Seven years later he was promoted to chief engineer and in 1951 was named assistant to the president of Landis Tool. Mr. Price has been granted 21 patents relating to the design of cylindrical grinding machines, and he has written several articles on machine tool hydraulic circuits and precision cylindrical grinding. He served on the original NMTBA committee of the Joint Industry Conference which established the hydraulic standards now used throughout industry.

◆

Robert M. Jones

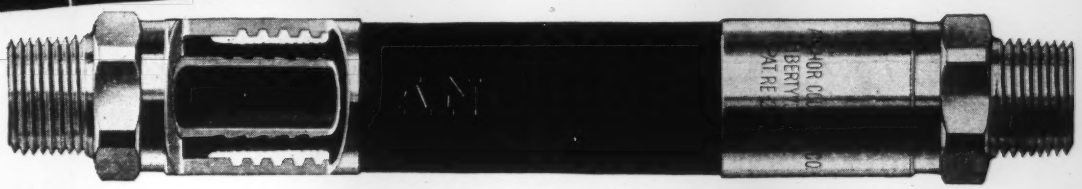
Saco - Lowell Shops has announced the appointment of **Robert M. Jones** as vice president in charge of research and development, a position formerly held by the late **Eugene C. Gwaltney.** A graduate of Massachusetts Institute of Technology, Mr. Jones joined the company in 1919 as a draftsman designer. He was placed in charge of production engineering in 1947 and served briefly as head of the production department. In October 1950 he was appointed chief engineer with supervision of both research and product engineering when these





◀ Close-up view of pump shows Anchor Hose and Ductile Sleeve Couplings.

Anchor Ductile Sleeve Coupling with exclusive patented grip. ▼



Bridge lifting job handled easily—

with high-pressure ANCHOR hose and ductile sleeve couplings

MINNEAPOLIS . . . Here's a difficult job recently performed on the Broadway Avenue Bridge. Four spans across the upper Mississippi, each weighing approximately 250 tons, were raised to provide 19 ft. additional clearance at one side of the river for the passage of boats and sloped to the existing level on the other side. Anchor Hose and Ductile Sleeve Couplings, well-known for dependability and safety, were used for transmitting the required high hydraulic pressures to the twenty 4" jacks under each span. The use of hydraulic hose and the principle of hydraulic lifting made it possible to do this unusual job.

Tough jobs like this point up the superiority of Anchor factory-assembled couplings and hose. The positive seal eliminates leakage even under extreme pressures. The exclusive, patented Anchor grip makes the coupling virtually a part of the steel reinforcing wire of the hose — prevents blow-offs.

These complete high-pressure hose assemblies are exactly tailored to your particular job. They assure a wide safety margin and fewer hydraulic equipment breakdowns.

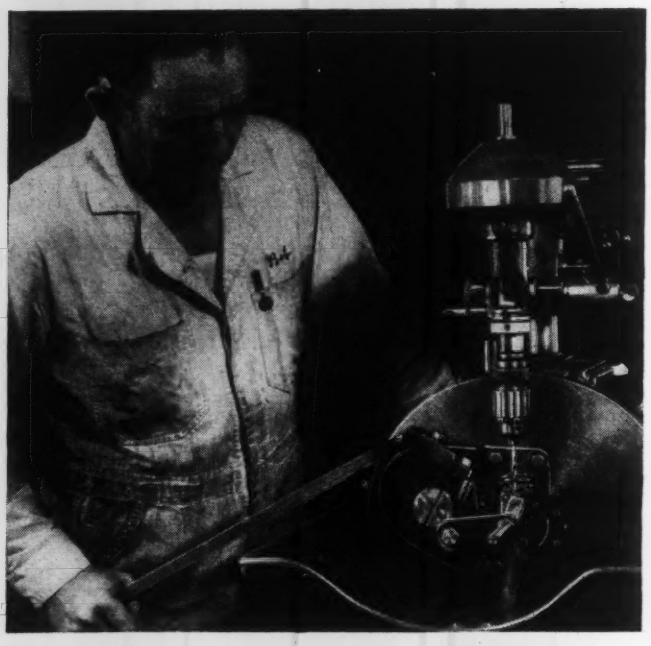
Typical uses of Anchor's complete range of flexible hose lines and couplings include high-pressure riveting, road machinery, coal mining equipment, machine tool applications, farm tractors, railroads, oil field machinery, and lubrication.

Find out how these time-, trouble-, and money-saving hose assemblies can improve your product — *Attach coupon to your letterhead and mail TODAY!*

ANCHOR COUPLING CO. INC.
LIBERTYVILLE, ILLINOIS
BRANCHES: DETROIT, MICHIGAN • DALLAS, TEXAS

ANCHOR COUPLING CO. INC.
Dept. MD-42, Libertyville, Illinois
I want to know more about Anchor Ductile Sleeve Couplings and Hose. Send me catalog sheets.
Name _____ Position _____
Company _____
Company Address _____
City _____ State _____

SAVE ALIGNING TIME and COST ON DIRECT-CONNECTED MACHINES



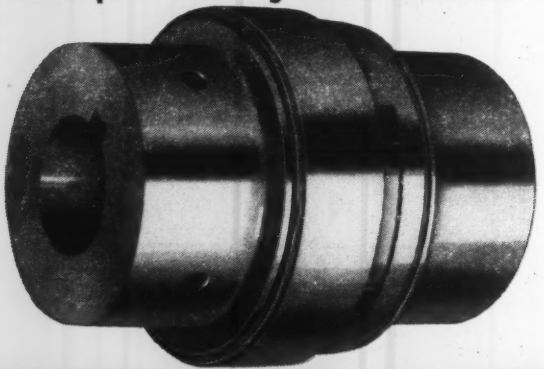
. . . Let

LOVEJOY FLEXIBLE COUPLINGS

DO THE JOB!

Lovejoy Flexible Couplings instantly and permanently correct for misalignment—absorb vibration, shock, back-lash and surge. New multiple leaf spring holds collar in place and permits 50% higher speeds with safety. No shut-downs for changing cushions . . . NO LUBRICATION EVER NEEDED! Cushions available for every duty . . . 1/6 to 2500 H. P.

Write today for complete catalog and quick-finding selector charts



LOVEJOY FLEXIBLE COUPLING CO.

5018 W. Lake Street **Chicago 44, Illinois**

Also Mfrs. Lovejoy Universal Joints and Lovejoy Variable Speed Transmissions.

two operations were consolidated into the company's engineering division. Mr. Jones worked with the Technical Industrial Intelligence Committee during World War II and was awarded a Certificate of Appreciation from the Secretary of the Army in May 1951 for this work. He is a member of both the American Textile Research and the British Textile Research Institutes and at present serves as secretary of the Textile Division of the American Society of Mechanical Engineers. Mr. Jones' headquarters are at Saco-Lowell's plant in Biddeford, Me.

♦

Orrin W. Barker

Orrin W. Barker, assistant chief engineer since 1936 at Kearney & Trecker Corp., Milwaukee, was recently named chief engineer. Mr. Barker has been associated with Kearney & Trecker since 1925. Upon completing his education in mechanical engineering at Milwaukee State Normal and the University of Wisconsin, he joined the Western Cartridge Co. as a designer. Subsequently he served in the same capacity at Ingersoll Milling Machine Co. and Nash Motor Co. In the field of machine tool development Mr. Barker has devoted his efforts principally toward bed type and special milling machine design and the application of hydraulics to machine tools in general. He is credited with a number of patents which the company possesses as the result of this work. Mr. Barker is a member of the Society of Automotive Engineers.

♦

Formerly assistant to the president, **Thur Schmidt** has been appointed director of research and development for the Ingersoll Products Div. of Borg-Warner Corp., Chicago. Mr. Schmidt has been engaged in research activities since 1937 and will now devote his efforts to the development of new manufacturing processes, as well as new products and markets.

♦

Morse Chain Co., Detroit, recently announced the appointment of **E. E. Wesselhoff** as assistant chief engineer. Mr. Wesselhoff has been associated with the company for 20 years and prior to his new appointment was manager of the Boston branch office.

♦

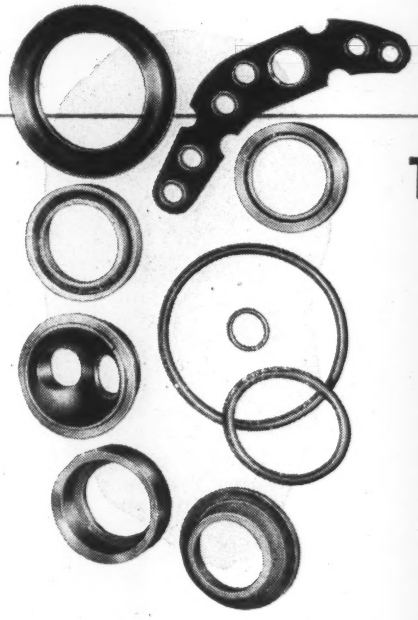
George Corsi, who for the past five years has served as plant engineer of National Motor Bearing Co. Inc., Redwood City, Calif., has been promoted to chief process engineer. In this capacity Mr. Corsi will be in charge of the mechanics and processes of manufacture in all of the company's four plants. Ap-

Meet Henry F. Eagan

Technical Director

International Packings Corporation
Affiliated with Graton & Knight Company

Study of materials and their components has been Mr. Eagan's life work, and he can be credited with many of the rapid advances in the use of synthetic rubbers. After graduating from Clark University with a B.S. and M.S. degree in Chemistry, he was an analytical chemist for 9 years. At Graton & Knight for 11 years, first as Chief Rubber Chemist, now as Technical Director of International Packings Corporation, it has always been his job to select the proper materials for a given packings application—and to supervise quality control in every stage of production. Member of the Rubber Division of The American Chemical Society and Society of Automotive Engineers.



In this series of advertisements we want you to meet the people who make G&K-INTERNATIONAL Packings.

There's a lot of experience in every approved packings compound

The best material for a given packings application demands detailed experience when selecting leather impregnants or compounding rubbers.

You'll be served best when your packings supplier can recognize your problem and apply to it the experience gained from many similar applications.

As manufacturers of packings since the turn of the century, G&K-INTERNATIONAL has a wealth of experience not only on the choice of materials, but also on manufacturing processes, application short-cuts, and the other details that mean more efficient packings.

G&K-INTERNATIONAL field engineers, backed by an experienced staff at the plant, are ready to work with you.

second century G and K — INTERNATIONAL

GRATON AND KNIGHT ESTAB. 1851

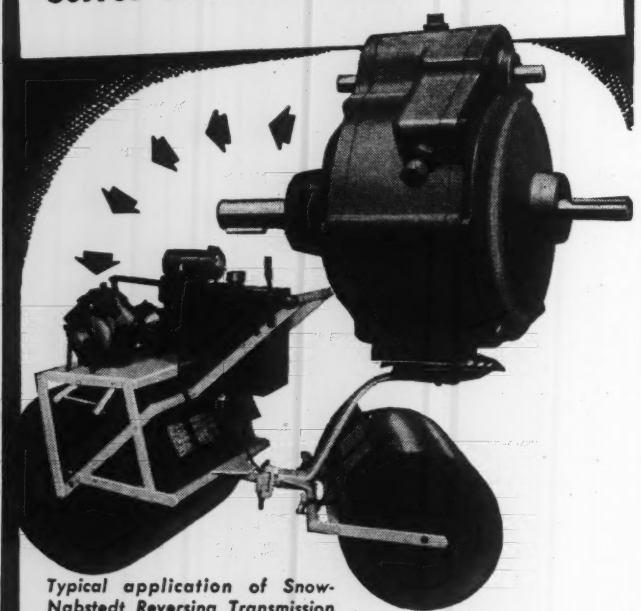
Leather and synthetic packings

GRATON & KNIGHT COMPANY
Worcester 4, Mass.

INTERNATIONAL PACKINGS CORPORATION
Bristol, New Hampshire

Amazing NEW REVERSING TRANSMISSION

Solves Numerous Design Problems



Typical application of Snow-Nabstedt Reversing Transmission by Gabb Mfg. Co., Windsor Locks, Conn. on its "Motoroller".

- SO UNIQUE — One unit combines forward, neutral, reverse and reduction . . . no separate clutch required! Has coaxial input-output shafts.
- AMAZING PERFORMANCE — Reverses occasionally, or frequently, under full load, without hesitation! Transmits 2 to 12 H.P. with 3.75: 1 reduction in both directions.
- HAS MANY APPLICATIONS — Suits design needs of machine tools, construction, agricultural, and materials handling equipment.
- REDUCES MAINTENANCE — is adjusted externally, without dismantling! Its pinions can't overheat; are long-lived.
- SAVES MONEY — Eliminates separate gear box, clutch, countershaft and mounting brackets in many applications. *SAVES assembly time, servicing problems, and improves product appearance.*
- SAVES SPACE — The most compact transmission available . . . only 9-1/16" x 8" x 9-1/2".
- QUALITY-ENGINEERED—Designed by makers of Joe's Famous Gears, world-renown for 46 years. Have our capable engineers produce transmissions to serve your defense equipment needs!

WRITE TO-DAY for descriptive bulletin or specify your needs, stating application, input and output speeds desired, H.P., power source, equipment to be driven.

THE SNOW-NABSTEDT GEAR CORP. REVERSE & REDUCTION S-N GEARS HAMDEN, CONN. U.S.A.

The **SNOW-NABSTEDT GEAR CORP.**

237 WELTON ST., HAMDEN, CONN., U. S. A.

pointed to succeed Mr. Corsi as plant engineer is **Joseph G. Bracco,** who has been associated for many years with the Larsson Machine Tool Works and with the Joshua Hendy Iron Works.

♦

Several promotions were announced recently by Bristol Engineering Corp., Bristol, Pa. **Arthur Paine** has been named chief of the aircraft design division; **Karl Koehler** has been promoted to chief of the mechanical design division; and **George Dixon** has been made chief of the electronics division.

♦

The appointment of **Alan G. Buckley** as assistant manager of construction engineering has been announced by Goodyear Tire & Rubber Co., Akron. Mr. Buckley will engage in engineering work for all Goodyear plants.

♦

Associated with the company for 30 years in various engineering capacities, **August B. Hepp** has been appointed chief engineer for the Logan Co., Louisville, Ky., manufacturer of power and gravity conveyors. Mr. Hepp has served as assistant chief engineer for the past seven years. He succeeds **H. R. Gotthardt,** who has reached retirement age but who will remain with the company as consulting engineer.

August B. Hepp

♦

George W. Jernstedt has been appointed manager of engineering for the Special Products Development division of Westinghouse Electric Corp. Mr. Jernstedt is at present in charge of electroplating projects and will continue in that capacity in addition to his new appointment.

♦

Julian G. Everett, Robert H. Hose and **William F. H. Purcell,** associates for many years in the Henry Dreyfuss industrial design organization, have been made partners in the firm. Also, **Doris Marks** and **Rita Hart,** who have been with Mr. Dreyfuss for a number of years, have been named associates.

♦

Former general manager of Link-Belt Company's Minneapolis plant, **L. J. Carson** has resigned from his position as price executive of the Machinery Branch of the Industrial Materials and Manufactured Goods Division of OPS and has been named general manager of Link-Belt's new Colmar, Pa., plant. Now under construction, this plant is scheduled to be in operation during the last quarter of 1952. Mr. Car-

Men who design, engineer and buy America's products rely on..and use..National Laminated Plastics because..

"In long range planning at National, emphasis is placed on engineering research. Designed to benefit National's customers and the entire industry as well, the operation breaks down into three broad divisions. *First*, testing materials against our standards and customers' specifications. *Second*, developing new products to meet specific customer requirements. *Third*, improving present manufacturing methods. In short we at National feel that engineering research provides our eyes and ears for the future."

John K. Johnston
Vice President
National Vulcanized Fibre Co.

Circuit Breaker Bushing Sleuth

George Holton, electrical scientist in National's lab, is testing a Phenolite circuit breaker bushing for dissipation factor at 60 cycles. Tests of this character are constantly carried on for production control and in the development of new products.

National Laminated Plastics nationally known—nationally accepted

NATIONAL VULCANIZED FIBRE

A tough horn-like material with high dielectric and mechanical strength. Excellent machinability and forming qualities, great resistance to wear and abrasion, long life, lightweight. Sheets, Rods, Tubes, Special Shapes.

PHENOLITE Laminated PLASTIC

Phenolite possesses an unusual combination of properties—a good electrical insulator, great mechanical strength, high resistance to moisture; ready machinability, lightweight. Sheets, Rods, Tubes, Special Shapes.

Just published! National Laminated Plastics Handbook.
Write for copy. Your company letterhead please.

National Vulcanized Fibre Company

Wilmington Delaware

Offices in *Principal Cities*

Since 1873

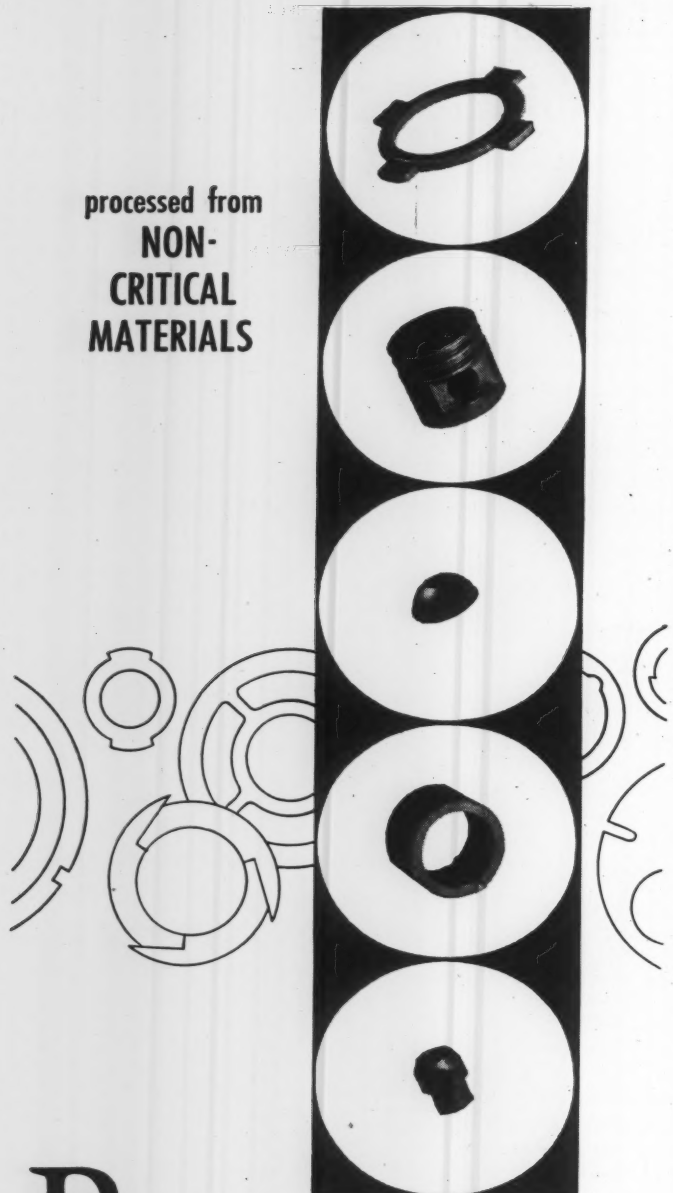
Hardness gets its full measure

Important in the production control and development of Phenolite and National Vulcanized Fibre is the degree of punchability of stock for meeting particular customers' specifications. This laboratory research operation with the Rockwell Hardness Tester is shown above.

Phenolite Varsity 1952

Here's the team of skilled scientists, captained by Gerald H. Mains, who occupy key positions at the Phenolite laboratory. They're evidence of National's continuing research program. Their combined know-how is quickly available to National's customers.

processed from
NON-
CRITICAL
MATERIALS



Purebon

may be your best bet for solving problems caused by sliding or rotating parts where lubrication is difficult or impossible.

The availability of Purebon during this period of restricted metals is a boon to engineers and designers faced with problems involving rotating or sliding parts which are difficult or impossible to lubricate. For such applications, Purebon mechanical carbon material is often the ideal answer. Typical applications are seal rings, bearings, pistons, piston rings, pump vanes, valve seats, meter discs, and a host of similar items. Purebon comes in a wide variety of grades. It is strong, tough, readily machineable and in many cases can be molded directly to size.

Bulletin No. 482 tells the complete story of Purebon. Write for your copy today.

PURE CARBON COMPANY, INC.
446 Hall Ave. St. Marys, Pa.

son began his career with the company in the engineering department of the San Francisco plant in 1935 and advanced to chief engineer of the Pacific Division. Subsequently he served as chief engineer of the Chicago Caldwell plant, and then as general manager of the Minneapolis plant.

♦

William H. Funk has been named assistant manager of the development engineering department of Lukens Steel Co., Coatesville, Pa. Associated with this department since its inception in 1945, Mr. Funk will now devote the greater part of his activities to development of new products and processes.

♦

Appointment of **Captain E. E. Roth,** USN (Ret.), as director of engineering, LVT Section, in the Kalamazoo, Mich., works of the Ingersoll Products Division of Borg-Warner Corp. was announced recently. He will direct the engineering and development of amphibian vehicles of a new post-World War II type which the Ingersoll division developed with the Navy. Captain Roth succeeds **Fred W. Cederleaf,** whose appointment as assistant to the works manager, with responsibility for the engineering and development of new defense projects, was also announced.

♦

Gilmore L. Stitely has been appointed chief design engineer of Spitz Laboratories Inc., Philadelphia. He comes to his new position from the Franklin Institute Laboratories for Research and Development, Philadelphia, where he has been a development engineer since 1946.

♦

At a recent meeting of the board of directors of Consolidated Vultee Aircraft Corp., San Diego, Calif., **Gen. Joseph T. McNarney** (Ret.) was elected president of the firm. He succeeds **LaMotte T. Cohu,** who was elected vice chairman of the board.

♦

Winfield B. Heinz, an electrical and mechanical engineer and owner of Heinz Engineering Co., Arlington, Va., has been named president of Dryomatic Corp., Alexandria, Va.

♦

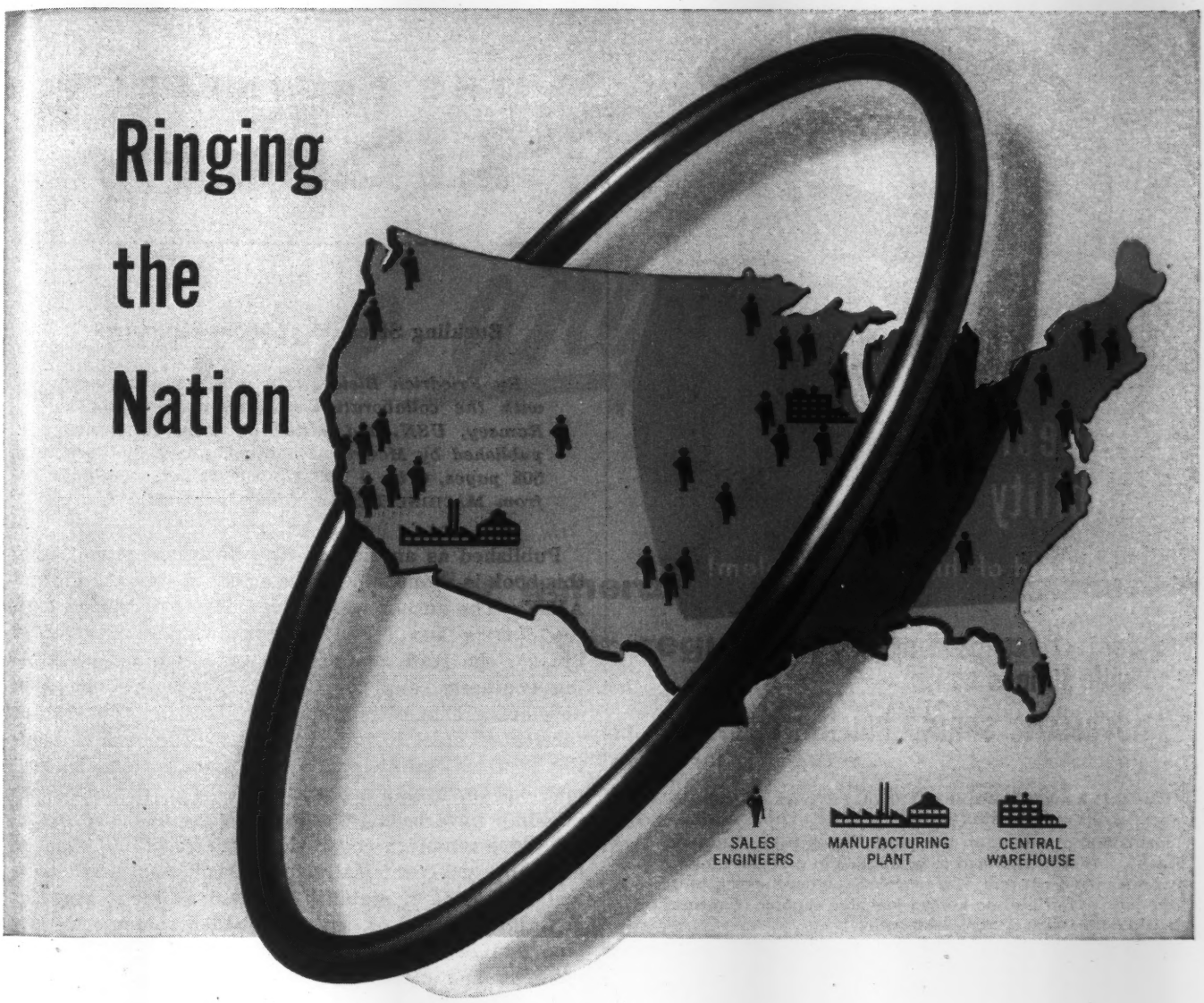
Michael C. Turkish was recently appointed chief engineer of the coil spring department of the Eaton Mfg. Co. spring division, Detroit.

♦

Howard Terhune has joined Loewy Construction Co. Inc., New York, a subsidiary of Hydropress Inc., as project design engineer in charge of the Counter-Blow Hammer Division. Mr. Terhune has specialized in drop hammers, forging equipment and heavy presses since 1906.

♦

A pioneer in powder metallurgy research, **Dr. Harry G. Mitchell** of the Speer Carbon Co., St. Marys, Pa., has received an award for outstanding accomplishment in the advancement of powder metallurgy and its greater application in industry. This award was presented by the Metals Disintegrating Co., Union, N. J., on the occasion of its thirty-fifth anniversary.



Arrowhead "O" Rings

GET IMMEDIATE ATTENTION to your "O" ring requirements from an experienced, qualified Arrowhead Sales Engineer located near you. The Arrowhead Service Organization of over two-hundred skilled men stretches from coast to coast with forty offices strategically located in the principal industrial cities of the U.S. These men are available in a hurry to assist you with any "O" ring problem. Your nearest Arrowhead representative can provide you with engineering design information, prices and application data.

Prompt deliveries are assured from stocks in the centrally located Ohio warehouse, from Arrowhead's West coast manufacturing plant or from the stock of distributors throughout the country.

Take advantage of Arrowhead's reliable, nation-wide service! Write today for the name of your nearby Arrowhead Sales Engineer.

"O" RINGS

AIRTRON DUCTS

ARCOSIL SILICONE RUBBER PRODUCTS

ARROWHEAD RUBBER COMPANY | *Division of National Motor Bearing Company, Inc.*

DOWNEY, CALIFORNIA (Los Angeles County)

FIRST commercial manufacturers of precision "O" rings; PIONEER fabricators of silicone rubber; ORIGINATORS of rubber-fiberglass ducting.

GET THESE VALUABLE ENGINEERING AIDS

ARROWHEAD "O" RING MANUAL contains illustrated design information and data on the selection, installation and proper use of "O" rings. DATA SHEETS designed to assist you in the selection of proper ring and most suitable compound. Write Dept. AR-10.

...with Springs by
AUTOMATIC SPRING COILING COMPANY

This clutch manufacturer was having a "peck-of-trouble"

The action of a lever in this particular type of clutch was such . . . that tension had to be applied in quite an unusual manner. And not only was there no standard spring to do the job . . . but also no known machine capable of turning out the necessary custom-built spring!

Then Automatic Spring Coiling Co. was called in . . . and we put *Engineering Ability* to work.

Our consulting engineers analyzed the situation . . . and designed a *special machine* to produce a special *spring* . . . which was also **Shot-peened* for fatigue strength, thereby adding immeasurably to its life potential.

Samples were made and put to repeated and conclusive tests. RESULT: More perfect clutch operation with guaranteed longer life and a considerably lessened chance for shock, slippage, vibration, grabbing and chattering.

Make it a point to consult Automatic Spring Coiling Company early in the job. Take advantage of our . . . ENGINEERING ABILITY . . . gleaned from 30 years of Precision mechanical spring specialization, and by strict adherence to Quality-Controlled standards.

**Incidentally*, "Shot-peened" *springs for added fatigue strength are among our specialties.*

Our veteran consulting engineers are ready to survey your requirements without obligation. Write us today for full details.

AUTOMATIC SPRING COILING CO.
4043 West Thorndale Avenue
CHICAGO 30, ILLINOIS

THE ENGINEER'S Library

Buckling Strength of Metal Structures

By Friedrich Bleich, late consulting engineer, with the collaboration of Commander Lyle B. Ramsey, USN, and edited by Hans H. Bleich; published by McGraw-Hill Book Co., New York; 508 pages, 6 by 9 inches; clothbound; available from MACHINE DESIGN, *$10.00 postpaid.*

Published as an Engineering Societies' Monograph, this book is sponsored by the ASCE, ASME, AIME and AIEE. The author worked in close co-operation with the Navy's David Taylor Model Basin (Bureau of Ships), the staff of Franklin and Lienhard, consulting engineers, and the Column Research Council in developing this reference volume on the behavior of fabricated steel structures under compression loading. Tables and simplified approximate formulas and methods for design are presented. Theories of elastic buckling have been extended into the inelastic range.

Twelve chapters cover the subjects of buckling of centrally or eccentrically loaded columns, mathematical treatment of stability problems and the stability criteria, buckling of centrally loaded columns by torsion and flexure, lateral buckling of beams, built-up columns and columns of variable stiffness, stability of frameworks, effective length of compression members in trusses and the stability of rigid-frame structures, stability of axially compressed bars elastically supported at specific points, local buckling of plate elements of columns, rectangular plates with longitudinal stiffeners, stability of web plates of girders, and special problems in the design of ship plating.

□ □ □

A New Approach to Engineering Tolerances

By J. Gilson; published by the Machinery Publishing Co. Ltd., London; 99 pages, 5½ by 8½ inches, clothbound.

This English book, according to the foreword, "makes an urgent plea for more realistic tolerances." Statistical analysis of tolerances is one of the main subjects, with a corollary investigation of tolerances obtainable with standard manufacturing processes, and methods of setting up a practical tolerancing system. The book is a good guide for comparing current (and forecasted) British practice with American practice in the same field.

Eight chapters are included in the book, subjects being: an introduction to tolerances; general toler-

The Dayton "Twins" solve any V-Belt problem!

For general purpose drives... over regular-diameter pulleys!

The famous Dayton Thorobred, with *three prime section* construction, is ideal for regular drives. 1. *Tension* section flexes easily over pulleys, without straining or cracking. 2. *Strength* section features electronically processed cords, for greater strength, and better bond with other sections of belt. 3. *Compression* section runs cool, gives more crosswise rigidity.

For "tough" drives...and to save space and weight.

The Dayton Cog-Belt*—for tough drives, or small pulleys! Scientifically built to bend as naturally as your finger, this premium belt delivers 40% more horsepower than conventional V-Belts. Easier bending lets you design drives with shorter center distances . . . smaller pulleys . . . 28% less weight . . . 47% less space. And even more important—5 Cog-Belts do the work of 7 conventional V-Belts!

*T.M.

Let Dayton help with your drive design problems. No obligation, of course. Just write, wire or phone DAYTON RUBBER COMPANY, DAYTON 1, OHIO.

V-Belts by **Dayton Rubber**

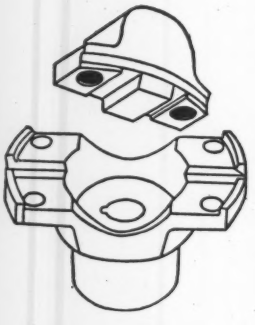
Since 1905

O D. R. 1952

WORLD'S LARGEST MANUFACTURER OF V-BELTS

if VIBRATION is Your Problem

Every high speed MECHANICS Roller Bearing UNIVERSAL JOINT and PROPELLER SHAFT is carefully B-A-L-A-N-C-E-D to reduce runout, whip and vibration to a minimum. Brake flanges and fitting yokes are statically balanced or accurately machined all over. Complete shafts are dynamically balanced, *at high speed,* and factory tested to insure smooth operation. The scientific design of MECHANICS Roller Bearing UNIVERSAL JOINTS eliminates all useless, unbalanced weight. The original alignment and balance are not disturbed when replacing MECHANICS cross-and-bearing assemblies, because the bearings and pilots are accurately ground to insure absolute centering and perfect fit.



MECHANICS
Roller Bearing
UNIVERSAL JOINTS

For Cars, Trucks, Tractors, Farm Implements, Road Machinery, Industrial Equipment, Aircraft

Let our engineers show you how this exclusive MECHANICS Roller Bearing UNIVERSAL JOINTS advantage will help improve the operation of your product.

MECHANICS UNIVERSAL JOINT DIVISION
Borg-Warner • 2032 Harrison Ave., Rockford, Ill.

ances for various production processes; effect of tolerances on fits; tolerance accumulations in assemblies; method of expressing tolerances on drawings; standard limit and fit systems; implementation of recommendations; and a concluding chapter on the implications of a rational tolerancing system.

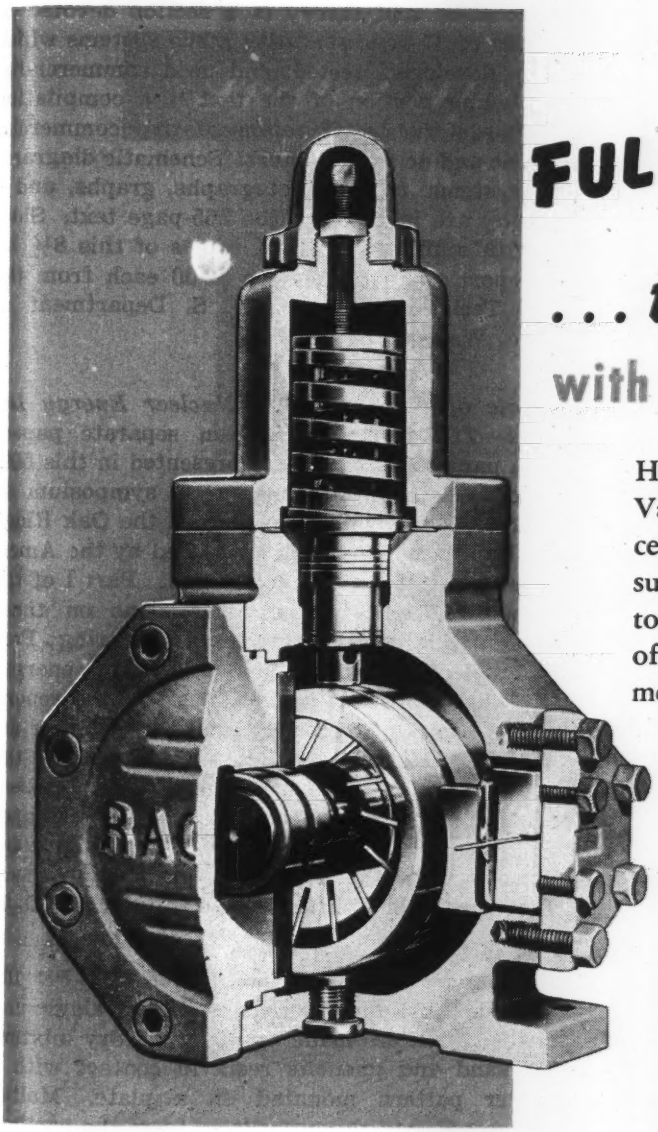
Government Publications

The Formation of Refractory Coatings by Vapor-Deposition Methods—PB 104288 *by C. F. Powell, I. E. Campbell, and B. W. Gonser:* As materials of construction and as protective coatings for high-temperature service, the high melting point metals of the third, fourth, fifth, and sixth periodic table groups, and especially their borides, carbides, silicides, and nitrides, are of potential utility because of their refractory nature. The most generally suitable methods for applying refractory coatings of this type involve the vapor-deposition processes. In these processes, a volatile compound of the metal to be deposited is passed over the work which is heated to a temperature at which the compound is decomposed, or reduced, at the surface to form an adherent coating. Coatings varying from less than a micron to several millimeters in thickness can be deposited at temperatures far below the melting points of the most refractory material utilized. These processes can be used to coat wire, die blocks, nozzles, jet and rocket engine parts, valves, bearing surfaces, etc.

This 97-page report summarizes the available literature on the formation of refractory coatings by vapor-deposition methods and includes the results of previously unpublished work at Battelle Memorial Institute on the evaluation of processes for the preparation of protective coatings for high-temperature service. A brief general description and discussion of vapor deposition is followed by appendixes which treat the individual materials and processes in detail. Paper-bound and side-stapled, the 8 by 10½-inch report is available for $2.75 a copy from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

Instrument Servomechanisms—PB 104 386 *by William J. Deerhake and Albert C. Hall:* Prepared at the request of the Special Devices Center, Office of Naval Research, this report was originally intended to comprise one chapter of a book on computing mechanisms. However, in its present form, the objective of the report is to provide sufficient background and technical information to enable those who utilize instrument servomechanisms to appreciate the possibilities and limitations of these devices. Although not intended as a complete reference volume for the design and development of instrument servomechanisms, the report does summarize information that has heretofore been widely scattered.

Beginning with basic terms and definitions used in the servomechanism field, the text goes on to explain the major components of servomechanism systems, the basic operational phenomena, and the characteristics of these systems. Following this gen-



FULL VOLUME HIGH PRESSURE

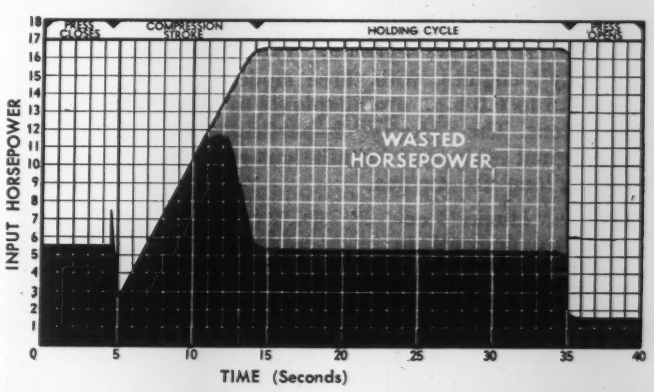
. . . BUT LOW HORSEPOWER

with RACINE *Hydraulic* PUMPS

High pressure holding is economical with RACINE Variable Volume Pumps. They will automatically cease their pumping action but maintain full pressure in the system. Instant change from no volume to full volume insures smooth, sure application of hydraulic force. Horsepower requirements are measured by the actual needs of the job — all of the oil is put to work.

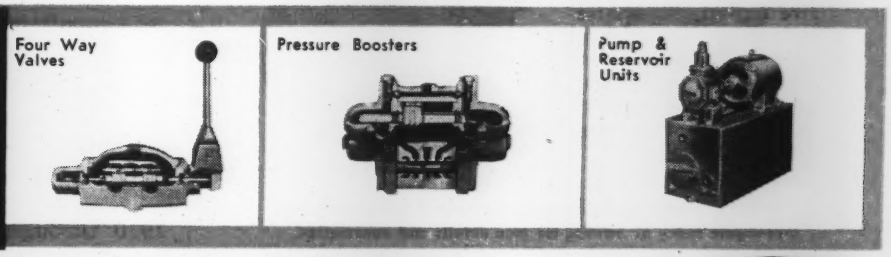
RACINE Variable Volume Pumps eliminate the need for relief valves — reduce oil heating — save horsepower and lower the over-all cost of most circuits.

Various standard governors are available for RACINE Pumps. These governors develop the pumping action that will best handle special requirements of the circuit. Maximum efficiency is assured.



The graph to the right illustrates the horsepower savings in a simple press circuit using a RACINE Variable Volume Pump and Pressure Booster. The colored area represents the bypassed oil from a constant volume pump —lost power that is saved with RACINE Equipment.

OTHER RACINE HYDRAULIC PRODUCTS



BUY DEFENSE BONDS

Write for complete catalog and engineering data.

RACINE TOOL & MACHINE COMPANY

1773 State Street, Racine, Wis., U. S. A.

RACINE

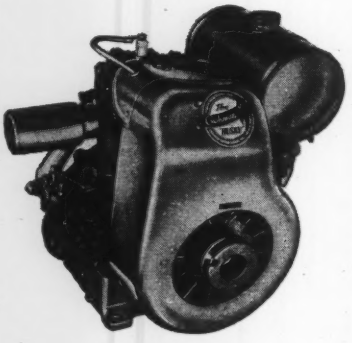
Industry depends on the

Cushman

"HUSKY"

The advance designed Cushman "Husky," a compact, lightweight engine has proved its worth over half-a-century of efficient and dependable service. Four-cycle, single cylinder, L-head Cushman "Husky" engines, with three models developing from 1.5 to 6.0 h.p., are adaptable to hundreds of operations. The "Husky" is particularly suitable for original equipment installations requiring high output, long life engines.

Sturdy "Husky" engines are designed to deliver their full rated horsepower hour after hour under load with maximum economy and minimum service and attention. Manual positive action, automatic and disc-type clutches, transmissions with forward and reverse gears, and other accessories are available for use with all "Husky" models.



Serviced Internationally by Cushman Motor Scooter Dealers
Investigate today by writing for free details and information.

CUSHMAN MOTOR WORKS, INC.
961 NO. 21ST ST. • LINCOLN, NEBRASKA

eral information and theory is a section devoted to descriptions of 11 representative servo systems which have been developed, tested, and used commercially. The concluding portion of the text is a compilation of the characteristics of representative commercial makes of ac and dc servo motors. Schematic diagrams of basic systems, tables, photographs, graphs, and a bibliography are included in the 265-page text. Side-stapled with stiff paper covers, copies of this 8½ by 11-inch report are available for $2.00 each from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

The Role of Engineering in Nuclear Energy Development—TID 5031: Seventeen separate papers as well as panel discussions are presented in this 509-page report of the proceedings of a symposium on nuclear engineering which was held at the Oak Ridge National Laboratory and was sponsored by the American Society of Engineering Education. Part I of the text presents general-interest discussions on those aspects of atomic power related to engineering; Part II covers scientific foundations of nuclear energy; Part III, which constitutes almost half of the report, is devoted to topics specifically related to reactor design; and Part IV, the concluding part, contains the panel discussion on nuclear engineering education. Tables and photographs are included in this paper bound, 8¼ by 11¼-inch report which is available for $1.40 a copy from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

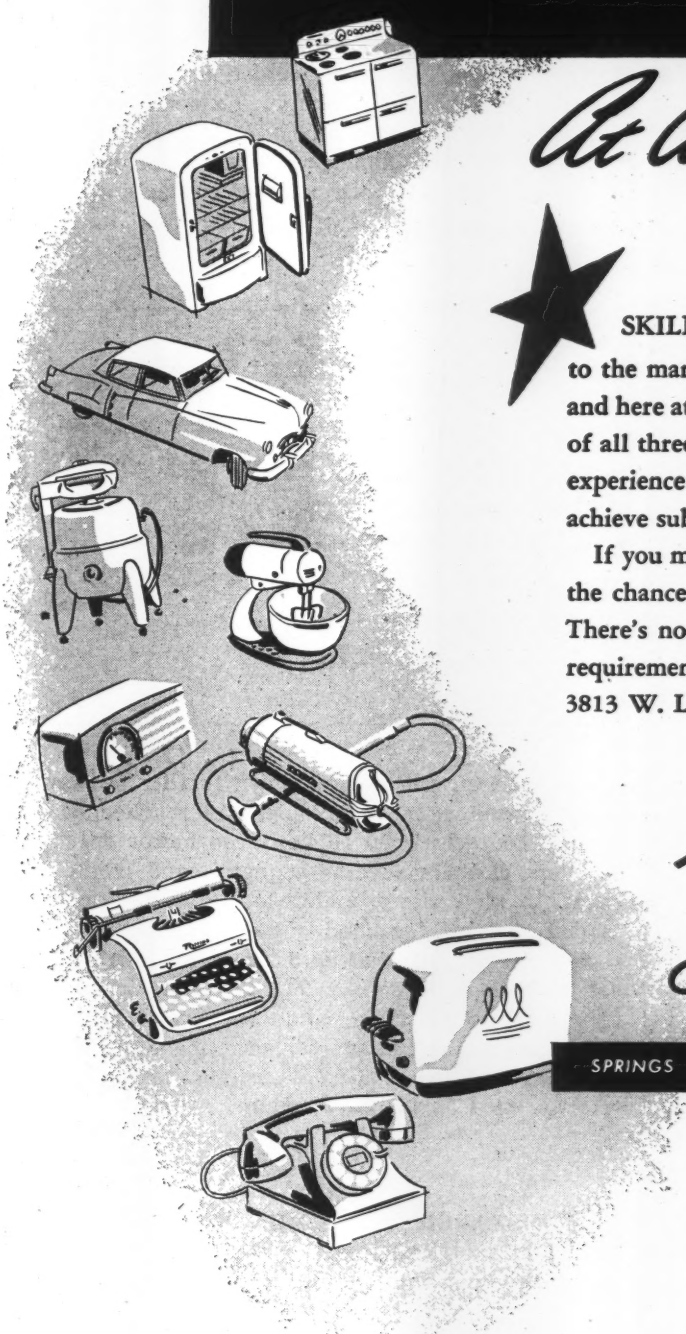
Plastic Bonded Shell Molding Simplified—PB 105 131: The shell molding process uses thin, single-use, shell molds which are made by placing a dry mixture of silica sand and phenolic resin in contact with a hot master pattern mounted on a plate. Molten metal is poured into these shells to form the casting. This 6-page pamphlet in the Navy's series of Industrial Notes presents full particulars for utilizing this process according to a procedure developed by the Navy. Copies of the pamphlet may be obtained for 25 cents each from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Bibliography of Books and Published Reports on Gas Turbines, Jet Propulsion, and Rocket Power Plants—National Bureau of Standards Circular 509 *by Ernest F. Fiock and Carl Halpern:* As the title indicates, this 64-page booklet presents references to published sources of information on gas turbines, jet propulsion, and rocket power plants. Also included in the listings are relevant publications on atomic energy. To aid in the use of the bibliography there is a brief introduction which covers the classification and rating of jet engines and discusses the scope and arrangement of the content. References, grouped according to subject, are for books published from 1910 through 1950 and periodical reports published from 1940 through 1950. Copies of the 5¾ by 9-inch, paper-bound booklet which supersedes Circular 482 are available for 20 cents each from the Government Printing Office, Washington 25, D. C.

Skilled Springmakers . . .

with a broad background of experience and engineering know-how produce better springs at lower cost

At Accurate



SKILL, experience and know-how are essential to the manufacture of better springs at lower cost . . . and here at Accurate, we are able to offer liberal quantities of all three. For many customers Accurate's skill, experience and know-how have made it possible to achieve substantial reductions in spring costs.

If you mass produce civilian or defense items, we'd like the chance to show you what we can do for you. There's no obligation. Just send an outlline of your requirements to ACCURATE SPRING MFG. CO., 3813 W. Lake St., Chicago 24, Illinois.

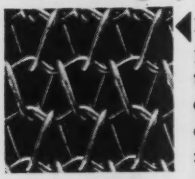
Accurate Springs

SPRINGS • WIREFORMS • STAMPINGS

Write for your copy of the Accurate Spring Handbook. It's full of useful data and helpful short cuts for making spring calculations.

No joke intended! This Cambridge Woven Wire Conveyor Belt carries cleaned fish through a wash tank to remove scales and scrap so the fish will present an attractive appearance on retail counters.

Cleaned fish are dropped from cleaning table A, onto the surface of conveyor belt B, passing through wash tank C. At the end of the tank hold down angles change the movement of the belt to a 60° incline. Stainless steel wire, used in weaving this belt, resists the corrosive attack of salt water in the wash tank, can be cleaned without damage by steam or by detergents added to the wash water.



In this application, BALANCED BELTING provides low original cost and controllable belt travel. ½" openings in belt weave permit free drainage of wash water and fish scraps. Angle cleats across the belt hold the fish during the movement up the incline.

This is a typical example of the many types of production and processing problems solved by the use of Cambridge Woven Wire Conveyor Belts. Cambridge belts can be constructed from any metal or alloy to a wide range of meshes and weaves. Don't fish around the next time you have a problem of combining movement with processing through heat, cold, liquids or corrosive agents . . . just call in your Cambridge field engineer for his experienced advice. Write direct or look under "Belting-Mechanical" in your classified telephone directory.

The Cambridge Wire Cloth Co.
Dept. N • Cambridge 4, Md.

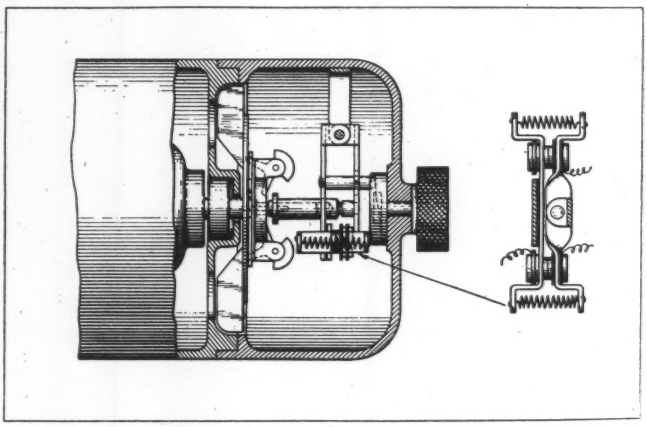
WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

FREE BELT MANUAL includes information on conveyor and conveyor belt design, metallurgical data and belt maintenance. Write for your copy today.

NOTEWORTHY Patents

DIFFERENTIAL TENSION SPRINGS in a speed-responsive governor provide staggered operation of double contact points to smooth out accelerative and decelerative action in an electric motor. The movable contacts of both pairs are insulator-mounted in a single bar which is pivot-coupled at the center to a centrifugally-operated linkage. Extreme ends of the bar are pulled toward an adjustable contact plate by helical springs of unequal tension, for example 5.9 oz and 6.1 oz when both pairs of contacts are closed. On acceleration of the motor, the contacts nearest the weaker spring will first separate, placing a resistance in the circuit to slow down further acceleration. When predetermined top speed is reached, the secondary contacts open to limit the motor speed. The contacts close in reverse sequence and if the motor tends to slow down under load, deceleration is retarded at predetermined speed by shorting out the resistance to give full-field operation until the preset top speed is regained. Manual operation of a face-type cam positions the contactor mechanism relative to the operating linkage for selecting a desired speed range. Patent No. 2,568,774 assigned to Birtman Electric Co. by Charles H. Sparklin.



ADJUSTABLE SHOULDER STUDS in a marine reverse-gear transmission enable proper backlash to be established and maintained between bevel pinion and gears without the necessity of machining the gear housing to close tolerances. This construction also permits individual pinion adjustment to be made without removing any parts of the assembly for fitting or shimming, since the threaded studs and locking screws are accessible from outside the housing. Ball bearings which carry the bevel gears are held

CLEAN SHEETS

You can make better products from clean, smooth, flat Chase Sheet Brass and Copper. Chase sheets are free from oxide coatings, excess grease and oil. That means they are uniform in color and have a bright finish.

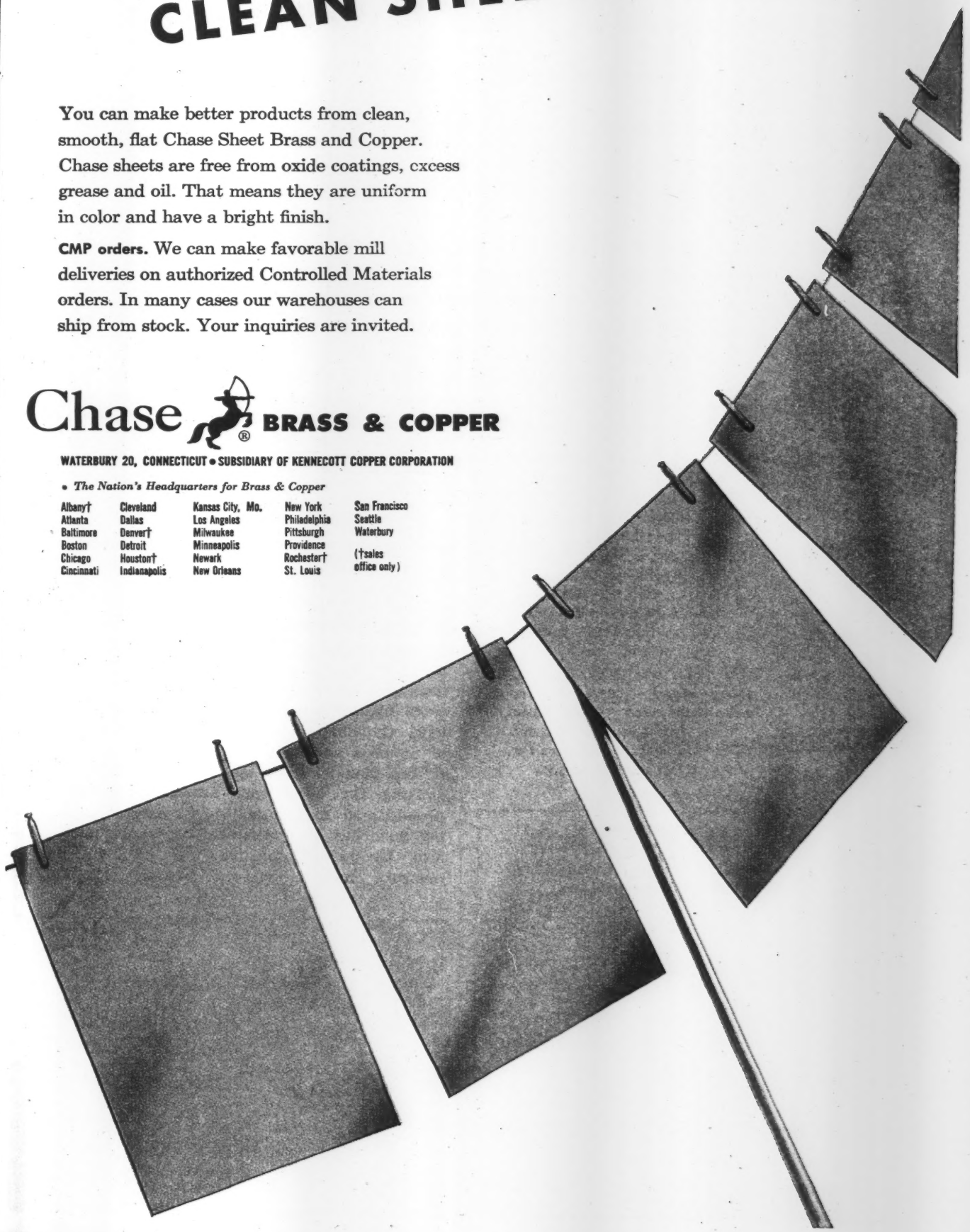
CMP orders. We can make favorable mill deliveries on authorized Controlled Materials orders. In many cases our warehouses can ship from stock. Your inquiries are invited.

Chase BRASS & COPPER

WATERBURY 20, CONNECTICUT • SUBSIDIARY OF KENNECOTT COPPER CORPORATION

• *The Nation's Headquarters for Brass & Copper*

Albany†	Cleveland	Kansas City, Mo.	New York	San Francisco
Atlanta	Dallas	Los Angeles	Philadelphia	Seattle
Baltimore	Denver†	Milwaukee	Pittsburgh	Waterbury
Boston	Detroit	Minneapolis	Providence	
Chicago	Houston†	Newark	Rochester†	(†sales
Cincinnati	Indianapolis	New Orleans	St. Louis	office only)



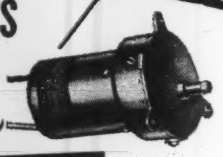
DESIGNING FOR DEFENSE?

UTILIZE COMPACT

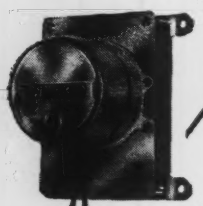
SYNCHRON TRADE MARK

TIMING MOTORS
TIMING MACHINES
CLOCK MOVEMENTS
D. C. MOTORS

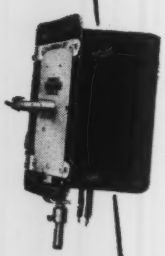
TIMING MOTORS



D.C. MOTORS



TIMING MACHINES



CLOCK MOVEMENTS

POWERFUL, PRECISE SYNCHRONOUS MOTORS

SYNCHRON synchronous motors meet your requirements for compact power. Pulls up to 8 oz. direct load continuously at 1 R.P.M. Gear trains can be furnished to convert to any speed. Unusual actions can be incorporated in movement. Our engineers will be glad to work with you in developing motors for special applications.

Hansen D. C. motors powered servo units which won Army-Navy E. Used also in aircraft instruments and radio control mechanisms.

Send NOW!

HANSEN
MANUFACTURING COMPANY INC.
PRINCETON, INDIANA

PLEASE SEND ENGINEERING DATA ON:

- ☐ SYNCHRON TIMING MOTORS
- ☐ SYNCHRON TIMING MACHINES
- ☐ SYNCHRON CLOCK MOVEMENTS
- ☐ MAGNA-TORC DIRECT CURRENT MOTORS

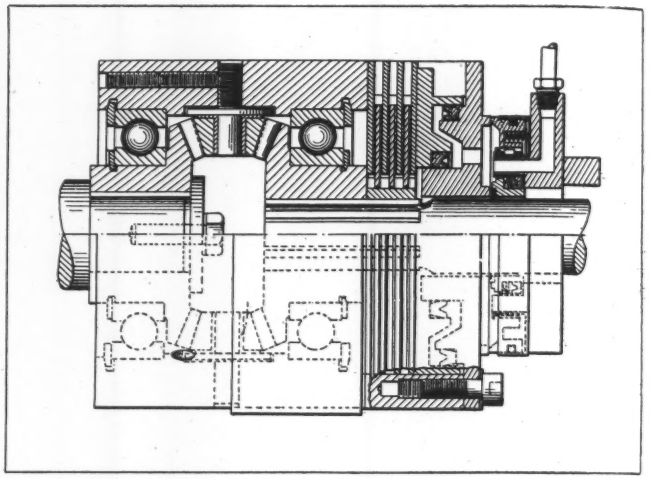
NAME .....

FIRM .....

ADDRESS .....

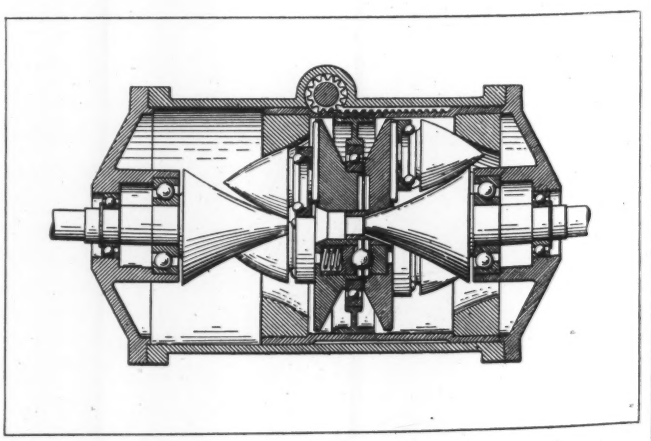
CITY..... STATE.....

MD



in place by tapered retaining rings to conserve space and facilitate assembly and servicing. The compact unit has a built-in multiple-disk clutch and a band-type brake which stops the housing during reverse drive periods. Both clutch and brake are actuated through a hydraulic control system. The transmission as illustrated is carried between power input and output shafts inside a housing having adequate oil capacity for lubrication and thermal dissipation. Patent No. 2,518,516 assigned to Charles E. Crofoot Gear Corp. by John T. Barron.

CURVOCONICAL PLANET ROLLER design in a frictional variable-speed transmission minimizes resultant bearing loads by maintaining roller contact with inner and outer cones in a common plane perpendicular to the roller axes. This design permits the use of lightweight ball bearings to support the planet members, thus reducing torque loss in the unit. Inner races of the bearings are integral parts of the rollers. Cup-shaped outer races key-guided on a pair of opposed spider plates permit radial repositioning of the planets when speed adjustment is made by shifting the outer race assembly. Axial pressure proportional to torque load is exerted on the rolling members by mechanical pressure changers built into the spiders. Located between the spiders, the pressure changers perform also as a coupling con-



WHY FARREL SPEED REDUCERS *STAND OUT* on jobs like these...

The design of Farrel speed reducers permits an engineering freedom in proportioning gears, shafts, bearings and even some housing dimensions to meet specific load, speed and service requirements. This flexibility has resulted in the solution of innumerable application problems.

In addition, Farrel speed reducers have a number of other advantages which account for their outstanding performance record in handling tough assignments. The quiet, vibration-free operation of the herringbone gears results from extreme accuracy of tooth spacing, contour and helix angle... qualities inherent in the Farrel-Sykes method of gear generation. Precision manufacture and highest grade materials contribute to long gear life.

Shafts and bearings are factored to safeguard against interruption of vital processes. Gear cases are proportioned to withstand repeated heavy peak loads. Joints are sealed to prevent entrance of dirt.

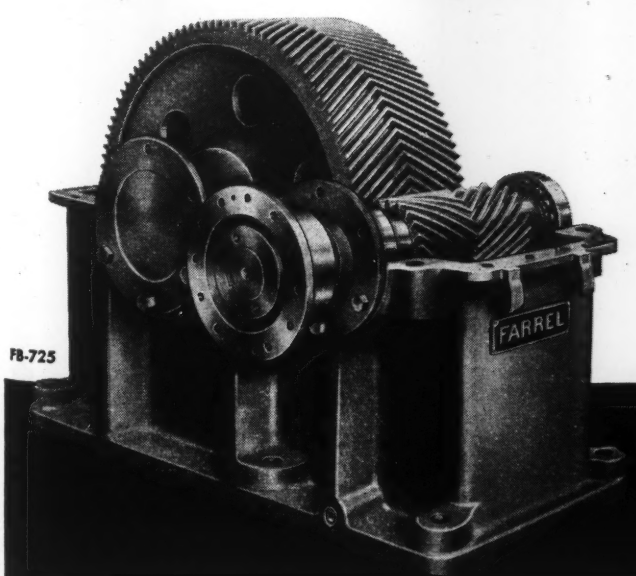
Write for further details of these outstanding units. Ask for a copy of Bulletin 449.

FARREL-BIRMINGHAM COMPANY, INC., ANSONIA, CONN.

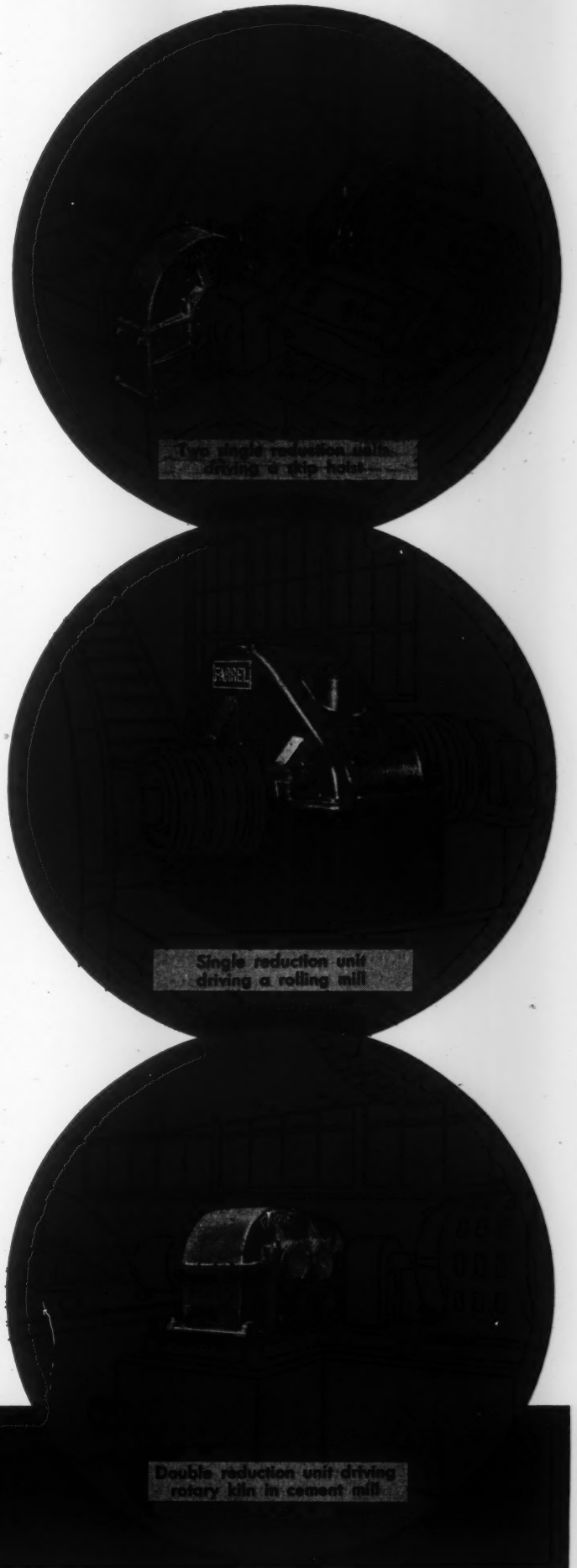
Plants: Ansonia and Derby, Conn., Buffalo, N. Y.

Sales Offices: Ansonia, Buffalo, New York, Boston, Pittsburgh, Akron, Detroit, Chicago, Portland (Oregon), Los Angeles, Salt Lake City, Tulsa, Houston, New Orleans

Farrel-Birmingham®



FB-725

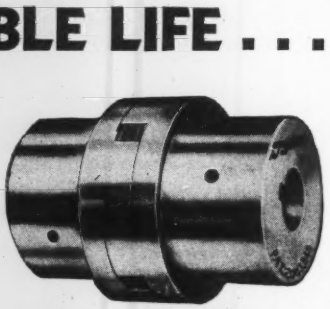


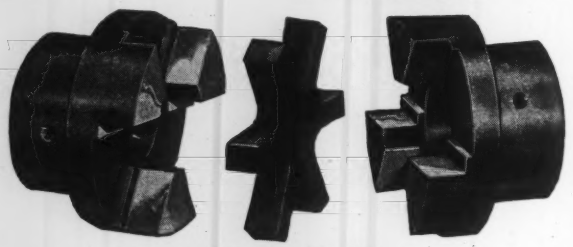
Single reduction unit driving a rolling mill

Double reduction unit driving rotary kiln in cement mill

Specify the Coupling that lives a DOUBLE LIFE . . .

The BONDTRU Coupling has double life. When the coupling is operating in one direction only, every second arm of the insert carries a load, while the remaining arms serve to prevent backlash. Should the load carrying arms become worn through long use, the insert can be moved up one position, putting in place the other set of arms which have remained unimpaired.





Patent No. 2,003,848
Canadian Patent No. 295,340

BONDTRU

Flexible

INSULATED COUPLING

The BONDTRU Coupling can be adapted with complete satisfaction to practically any application where a flexible connecting medium is required to transmit from 1/4-h.p. up to 100 h.p. at 100 r.p.m.

EASY ON BEARINGS—The self-aligning feature of the BONDTRU Coupling minimizes wear on the bearings by compensating for both lateral and angular misalignment of the driving and driven shafts.

NO MAINTENANCE NEEDED—Another advantage of the BONDTRU is that it has no moving parts—nothing that needs lubrication.

For complete information on Bond Flexible Insulated Couplings, write for Catalog No. F-24.

Carried in stock by
DISTRIBUTORS IN PRINCIPAL CITIES
(Write for name of nearest distributor)

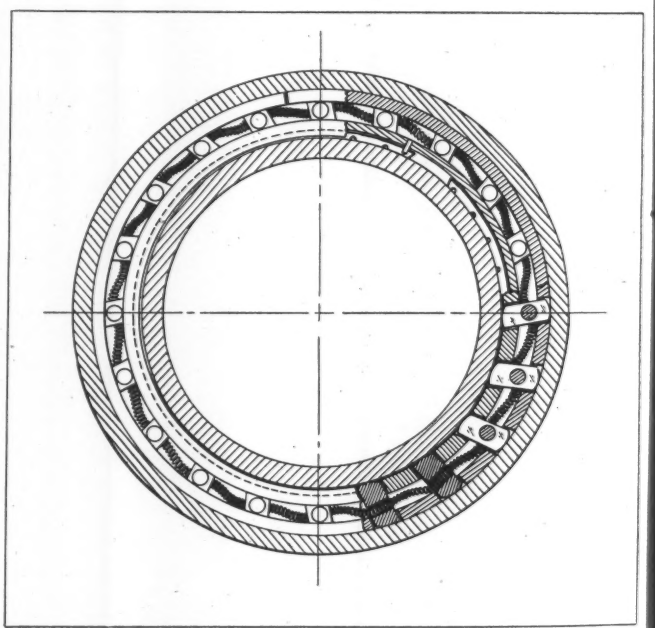
CHARLES BOND COMPANY
617 Arch Street, Philadelphia 6, Pa.

Bond®

STOCK GEARS
SPEED REDUCERS
FLEXIBLE INSULATED COUPLINGS

sisting of steel balls held normally on center between sets of spherically cupped plugs in the spiders. One of each set of plugs is compression-spring loaded, and should the output spider lag because of increased load, the tendency of the balls to roll out of the sockets compresses the springs additionally to increase the roller contact pressure proportionally. Patent No. 2,559,230 assigned to Roller Gear Corp. by Henry Schottler.

SELF-WRAPPING RINGS in a sprag-type freewheeling clutch insure prompt load pickup by causing the sprag cage to respond more readily on acceleration of the driving race. The rings are preformed with inside diameter slightly less than the mating surface of the race and are notched inside to prevent heavy oil-film formation between the friction surfaces. Anchor pins in the carrying grooves of the cage hold



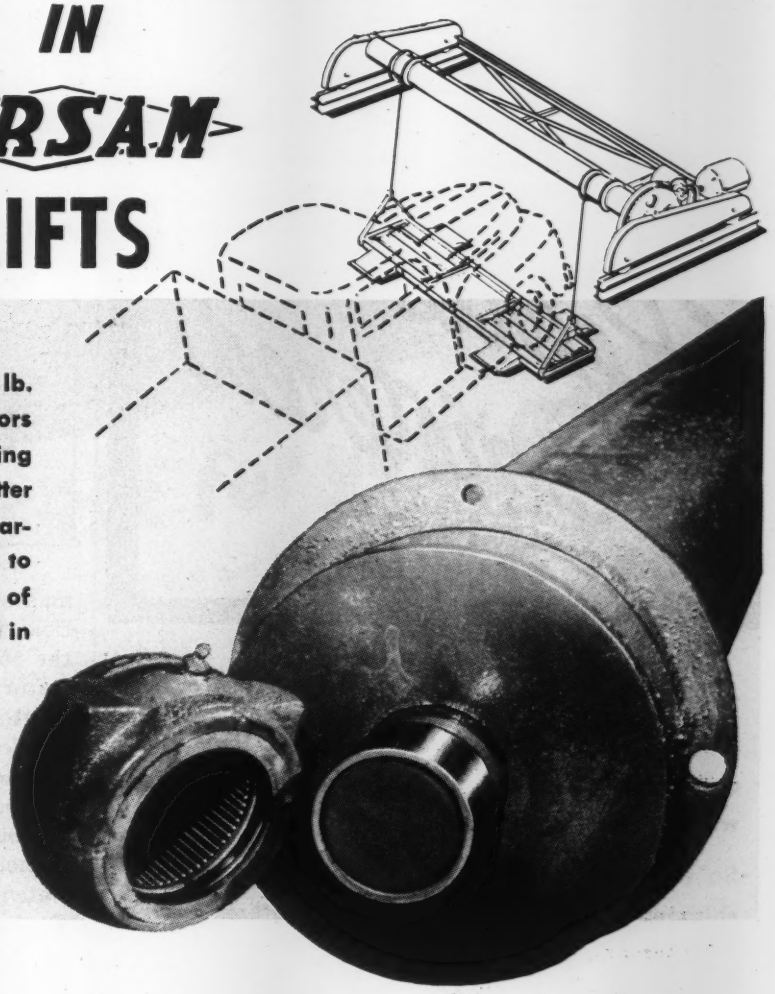
the rings at one end, while the other ends are free. In freewheeling direction the rings tend to unwrap, thus minimizing friction and subsequent wear. The inner surfaces of the rings are plated with copper to enhance their wearing quality and the resultant frictional force in wrapping direction is said to be three or more times that when freewheeling. Patent No. 2,576,337 assigned to Ford Motor Co. by Eugene J. Farkas.

SPRING KICKOFF counteracts the effect of residual magnetism that would ordinarily tend to prevent immediate release of the plunger in a vertical solenoid valve. In energized position, the spring is held compressed in a retaining groove in the plunger head. On de-energization of the coil, the normal releasing force caused by gravity is augmented by the spring force to prevent possible sticking because of residual

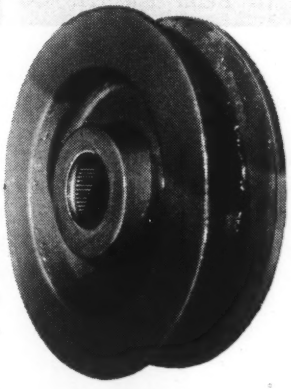
ORANGE ROLLER BUSHINGS

assure friction-proof operation of heavily loaded shafts IN

EHRSAM TRUCK LIFTS



Ehrsam Truck Lifts, in models up to 16,000 lb. lifting capacity, are used in grain elevators to raise the front end of farmers' trucks, causing grain to empty into bins and cars in a matter of seconds. Ehrsam engineers required bearing with high load capacity in small space, to provide anti-friction support at both ends of the Cable Winding Drum and in four wheels in the traveling frame. Orange Roller Bushings were selected, and after four years' experience, excellent performance is reported by Ehrsam Manufacturing Co., Enterprise, Kansas.

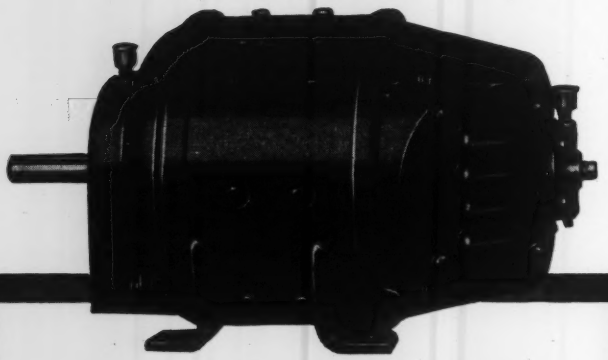


Full range of stock sizes from ½" to 8" shaft diameters. Write for Engineering Data Book. Representatives from coast to coast.

Wherever you have a shaft or part that rotates or oscillates, it can be "friction-proofed" with Orange Roller Bushings at low cost—and with little space. The benefits are many: More compact design—better operating characteristics—smoother, quieter running—elimination of "trouble-spots" and complaints. Orange Roller Bushings are the designers' standard for high load carrying capacity in small space. Extremely even running and long service life are due to closer internal running clearances, which minimize possibility of mis-alignment of rollers. Orange Roller Bushings are precision heavy duty needle bearings, widely used in the most accurate machine tools, as well as in all types of heavy equipment.

ORANGE

ORANGE ROLLER BEARING CO., Inc. 556 Main St., Orange, N. J.



ALL PEERLESS MOTORS ARE "Peerless Registered"

MORE than 90% of all Peerless Motors are custom manufactured to meet the specific operating requirements of the equipment with which they are to be used.

So we "Peerless Register" every motor before shipment. The words "Peerless Registered" are a trademark, recorded in the U. S. Patent office. Only Peerless Motors can bear this phrase, and only Peerless Motors offer you this protection.

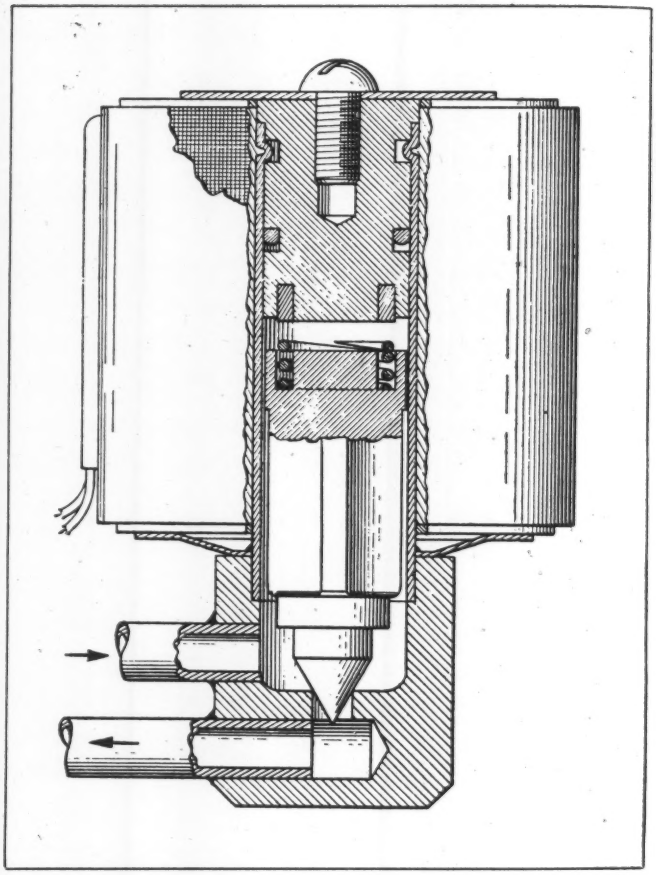
This registration record is assurance to both you and your customer that the Peerless Motor has been properly designed for your equipment so as to give best possible performance and long, satisfactory service. And the registration record makes possible the quick identification of any Peerless Motor — anywhere.

THE PEERLESS ELECTRIC CO., WARREN, OHIO

Manufacturers of Quality Motors Since 1893

Single Phase • Polyphase • Direct Current • ¼ to 15 H.P.

ALL Peerless Motors ARE "PEERLESS REGISTERED"



magnetism. To avoid interference with the magnetic field, the spring is centered in the plunger head within the boundaries of a copper shading coil pressed in the stator for the purpose of minimizing ac hum. The pointed plunger, which is also the valve stem in this case, operates in fluid inside a tubular guide brazed to the valve base. An O-ring prevents fluid leakage past the plug. A diaphragm spring on the outside of the guide tube supports the solenoid coil which is held in place by a retaining screw and washer. Patent 2,574,762 assigned to Penn Electric Co. by Paul Schell.

TAPERED AIR GAP improves armature stability in fractional-horsepower electric motors of single-bearing construction by reducing the effect of unequalized magnetic forces on imperfectly-contoured or slightly displaced lamination in the rotor. Where a conventional design would have a uniform air gap of 0.015-inch, substantially the same efficiency is obtained by maintaining this gap at the midsection, and tapering the rotor or stator laminations 0.010-inch in overall length. Thus, the magnetic flux is concentrated near the motor bearing where it is least likely to cause shaft deflection in the event of imperfectly contoured laminations. The tapered gap principle is said to make practical the building of longer, hence, more powerful motors in a given diameter housing than has been customary in motors of this type. Patent No. 2,575,153 assigned to General Electric Co. by Lawrance W. Wightman.

Whether you want one worm-gear speed reducer or a thousand, a standard drive or a unit designed to meet your special problems, Cleveland is prepared to serve you. Meeting the most difficult requirements of machinery manufacturers and users is Cleveland's everyday business.

Just off press...FREE for your asking

YOU'LL find first aid in this new Cleveland catalog — whenever you have to select worm gearing or an efficient worm-gear speed reducer.

Catalog 400 replaces our old Catalog 200. Its 180 pages illustrate and describe each model in the complete line of Cleveland Worm Gear Speed Reducers. It contains engineering data on each type, including dimensions, weights and horsepower capacities—all the information you need to arrive at proper selections of drives for any equipment.

Over a year in the making, Catalog 400 is now available to all our customers. If you can use one in your work of designing power-driven equipment, or selecting speed reducers for new or old machines, just drop us a line on your letterhead.

The Cleveland Worm and Gear Co., 3265 East 80th Street, Cleveland 4, Ohio.

Affiliate: The Farval Corporation, Centralized Systems of Lubrication. In Canada: Peacock Brothers Limited.

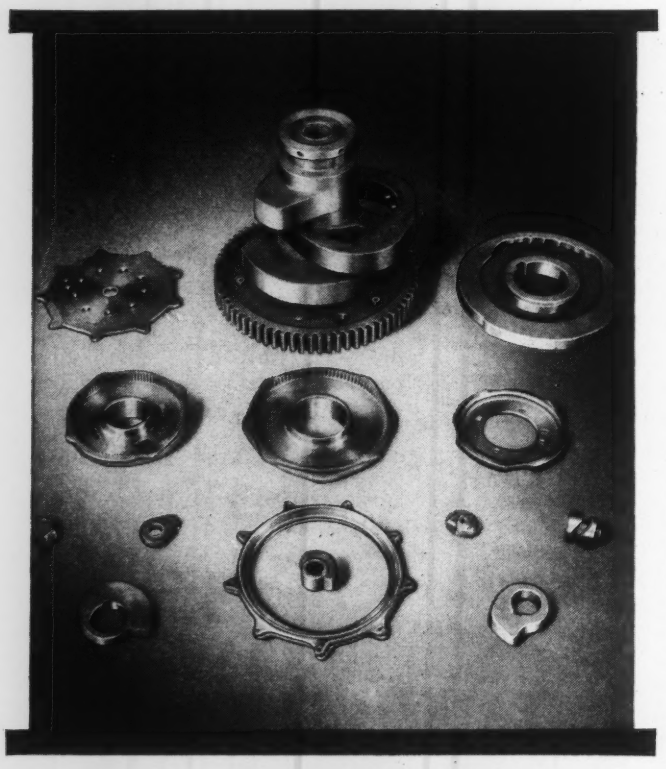
KUX

EXPERTS AT

CAM

CUTTING and GRINDING

The largest, most completely equipped plant in the country devoted to CAM cutting and grinding is at your service. 25 YEARS of experience in making special cams for thousands of companies has made us experts at cam cutting and grinding. Our facilities and equipment, finest in the country, permit us to manufacture any style or size Cam, Geneva Motion or Scroll Plate in quantities of 1, 10 or 10,000. Accuracy can be maintained to split thousandths, and surfaces to micro-finishes. Send us specifications or blueprints and we will be glad to submit a detailed quotation on your requirements.



KUX MACHINE COMPANY

6725 NORTH RIDGE • CHICAGO 26, ILLINOIS

Safety Control

(*Concluded from Page* 210)

Returning the engine starting-valve to its normal closed position opens a vent in that valve and relieves the pressure in the reservoir and the piston air valve. The oil pressure check valve maintains sufficient pressure on the bellows of the lubricating oil pressure valve until safe lubricating pressure is reached and the lockout valve is changed to the "run" position.

Automatic Operation: After the engine has been started and the valves set for their running positions, only one pressure circuit remains. This circuit, connected directly to the starting air supply, passes through the lubricating oil pressure valve, the jacket water temperature valve, and the engine overspeed valve to the fuel vent valve and engine fuel control valve. The rest of the system is vented to the atmosphere.

Fuel is shut off whenever the pressure on the fuel control valve is reduced. This pressure reduction may be caused by several different unsafe operating conditions.

A drop in lubricating pressure below the safe limits of operation actuates the pressure element of the lubricating oil pressure valve, shuts off the starting air supply, and vents the engine fuel control valve through the reservoir to the engine starting valve.

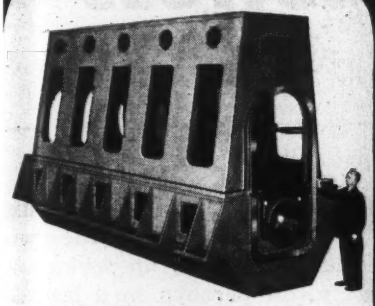
The jacket water temperature valve, *Fig.* 2, is operated by water temperature on a remote bulb through capillary tubing. Excessive temperatures actuate the bellows of this valve to close off the bottom port and vent the fuel control valve to the engine starting valve.

Excessive engine overspeed is prevented by a three-way valve, spring closed but normally latched open. In run position the valve is open from inlet to outlet. At excessive speed a spring-loaded plunger in the engine flywheel moves a trip lever and unlatches the valve roller lever. The valve inlet closes and a vent to the atmosphere is opened, bringing about fuel shutoff.

Fuel shutoff will also be caused by mechanical failure of the fuel control valve or the lubricating oil pressure valve, or by failure of supply air pressure.

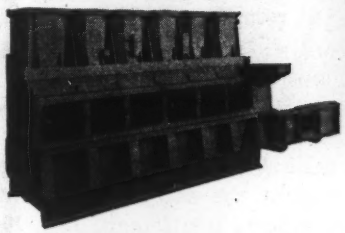
"We are now in a period of national emergency. It is not just a government emergency, and the production and engineering problems it entails cannot be met solely with the resources in industrial know-how normally available to the government. I think it is important that each of us develop a feeling of responsibility and obligation to our government that transcends our private ambitions. Further, I suggest that for the next several years every company of even moderate size must be prepared to release men for governmental posts; and where necessary and possible, to subsidize them during their terms of service."—T. KEITH GLENNAN, *commissioner, U. S. Atomic Energy Commission*

Steel-Weld FABRICATION

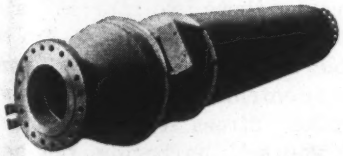


Crank Cases, Frames, and other Parts for Manufacturers of Marine Steam Engines of Uniflow or Multiple Expansion Type.

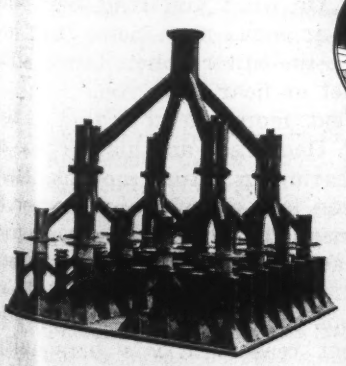
Heavy Press and Machine Frames and Bases for the Machine Tool Industry.



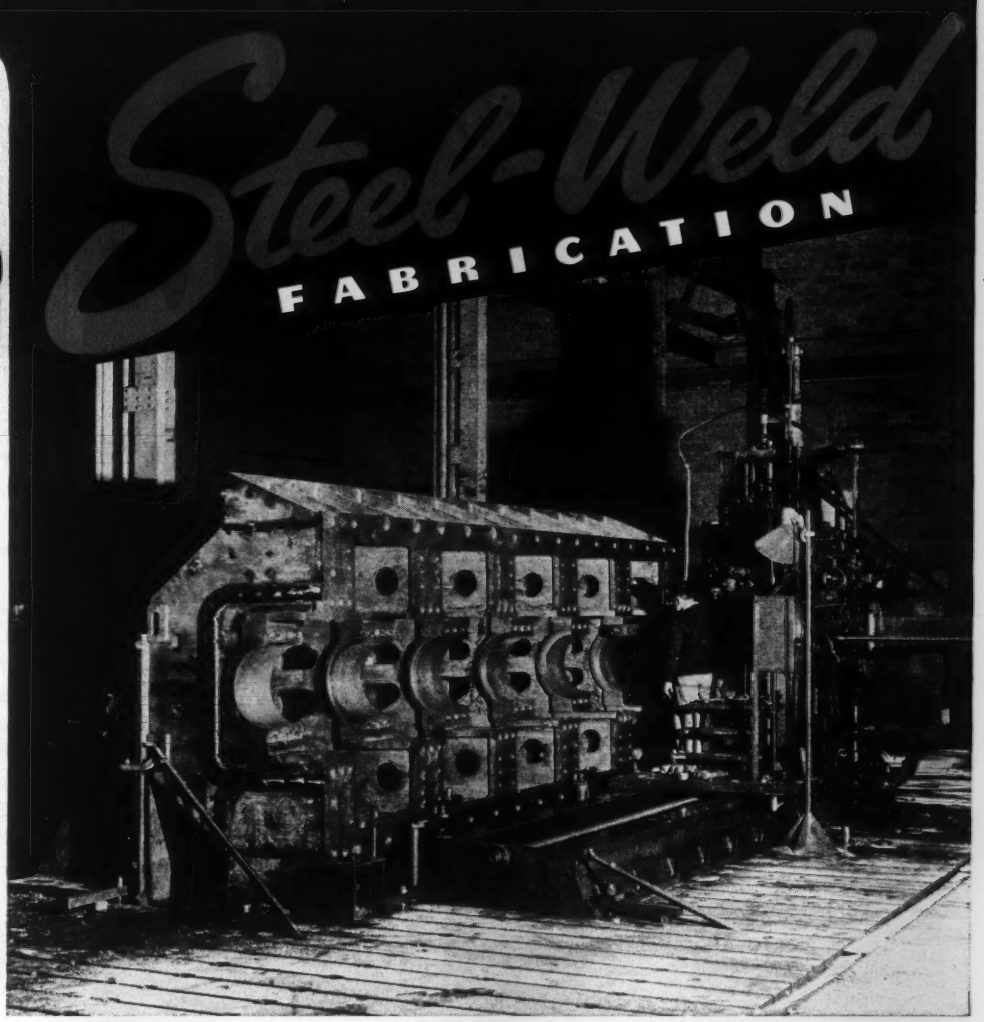
Diesel Engine Crank Cases and Frames for the Marine and Electro-Motive Field.



Pressure Vessels for the Chemical and Allied Industries.



One of Several Parts of a Catalytic Cracking Plant Produced for the Petroleum Industry.



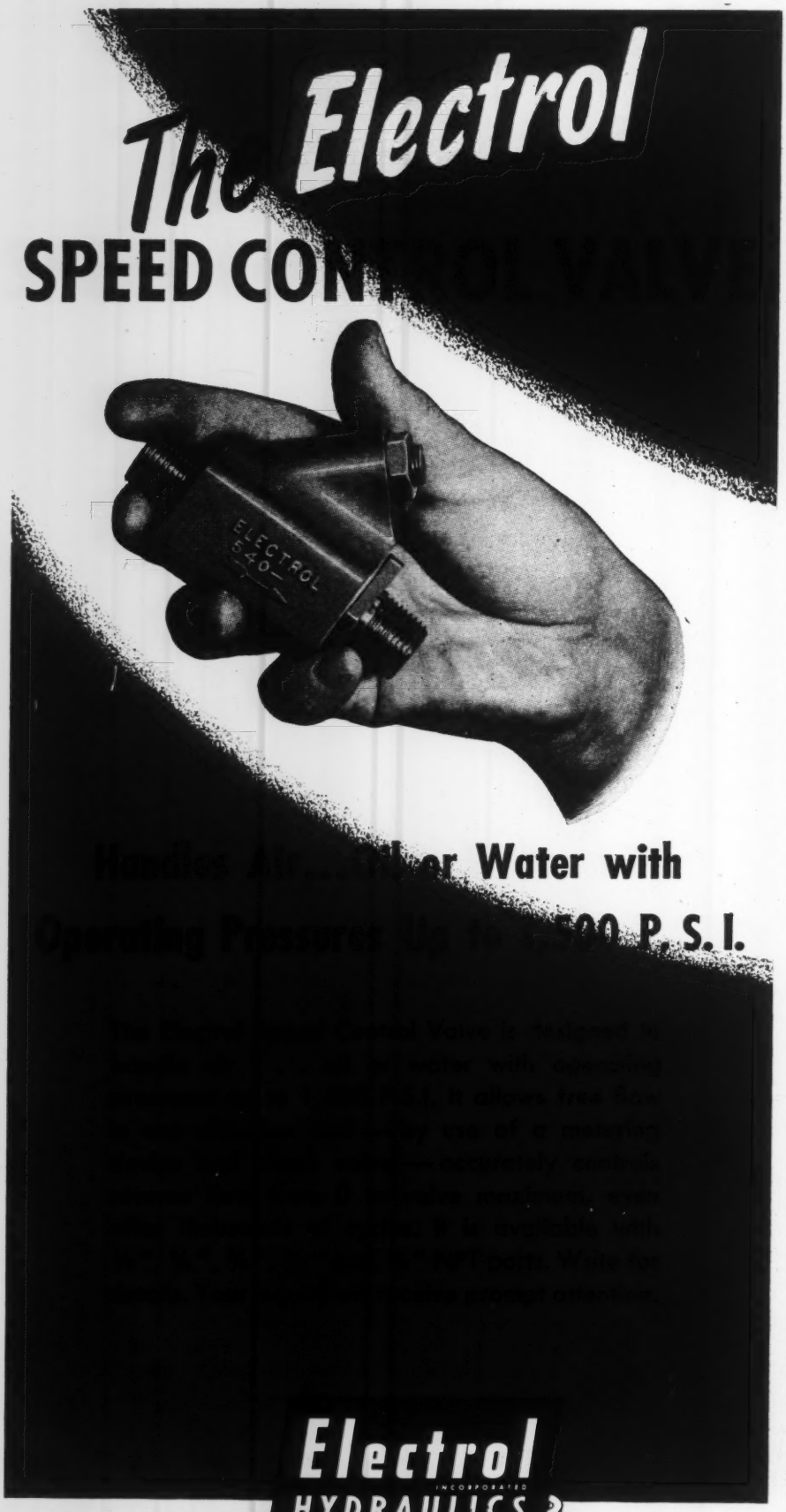
Use WELDED STEEL for Greater Strength with Less Weight!

The eleven ton marine engine crankcase, illustrated above, is another excellent example of how Steel-Weld Fabrication can be employed to good advantage in many products. It is typical of parts and assemblies produced by Mahon for many manufacturers throughout the country. Do you have bases, frames or parts in your product that could be redesigned for more economical production in welded steel? . . . do you have a new product in the development stage where Steel-Weld Fabricated parts could reduce weight without sacrificing strength? . . . are you faced with a limited production on an item which makes pattern costs prohibitive? . . . if so, it will pay you to investigate Mahon facilities and technical services. You will find in the Mahon organization a unique source with complete, modern fabricating, machining and handling equipment to cope with any type of work regardless of size or weight . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures you a smoother, finer appearing job, embodying every advantage of Steel-Weld Fabrication.

THE R. C. MAHON COMPANY
DETROIT 34, MICHIGAN

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON



Stress Relief

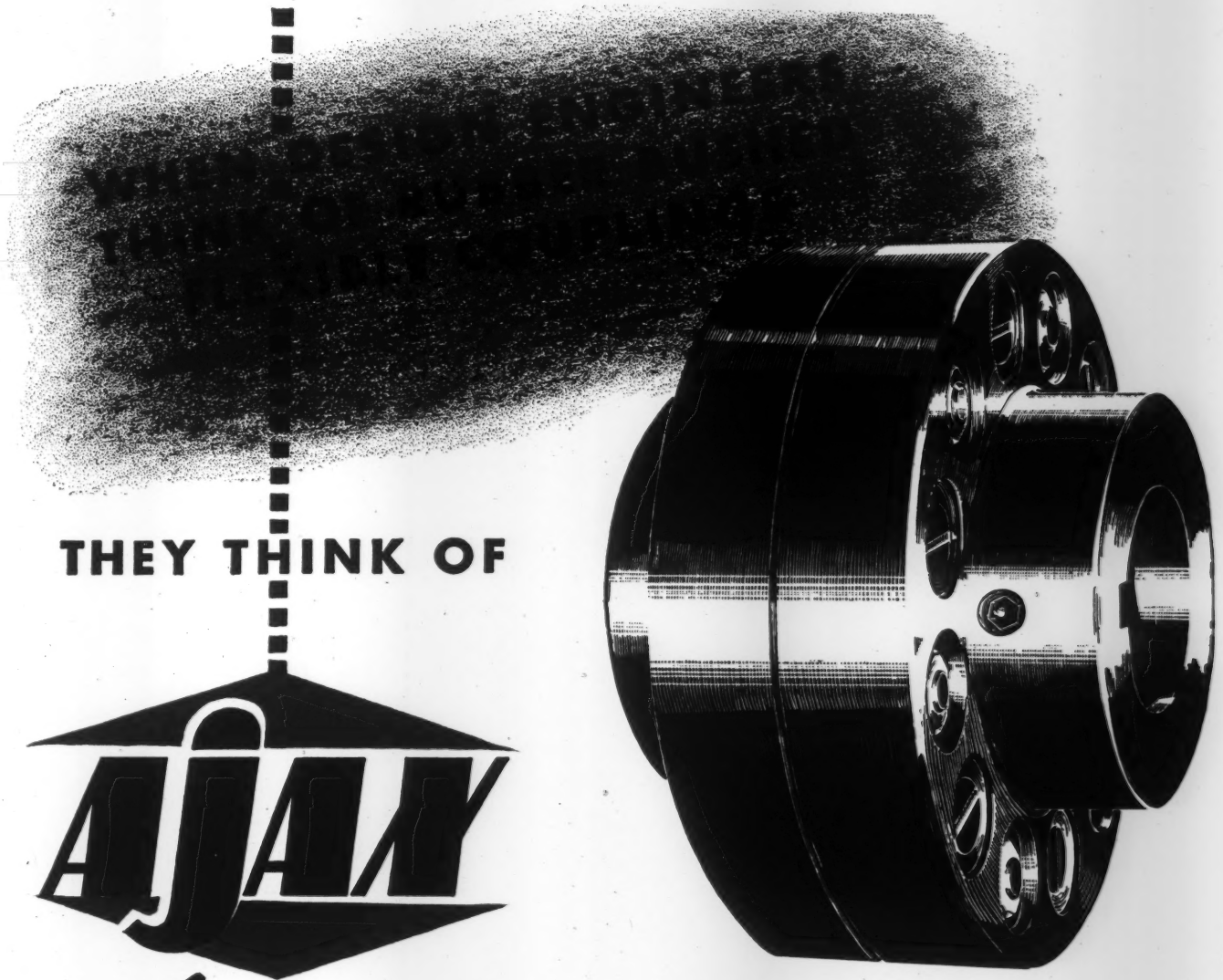
HERE we initiate a new MACHINE DESIGN feature. Since the above title might conjure up several diverse ideas, perhaps we'd best detail what "Stress Relief" will set out to do in this same spot in future months.

This new department will be a place in MACHINE DESIGN for informal discussion of the more-or-less personal factors that influence or are influenced by engineering work. It will be far less profound —technically—than the main section of this publication. Nevertheless, these modest discourses will bear strongly upon design, for they will be concerned chiefly with the men doing the job—with engineers and designers.

Who will originate these little gems? Well, we—the editors of MACHINE DESIGN—expect to ride the white charger occasionally in delivering suggestions or ideas gleaned from our observations in the field. Also, we will be privileged to present the salty commentaries of an elderly gentleman, J. P. Henderson, who has become through the years a valued friend of ours.

Besides these two sources, you—MACHINE DESIGN readers—are expected to come through with some vital contributions. As you see more of "Stress Relief," you may find yourself harboring the urge to purge your mind of an idea or two. Or what you read here—its pros or cons—may incite that letter-to-the-editor spirit. Don't stifle it; let us hear from you.

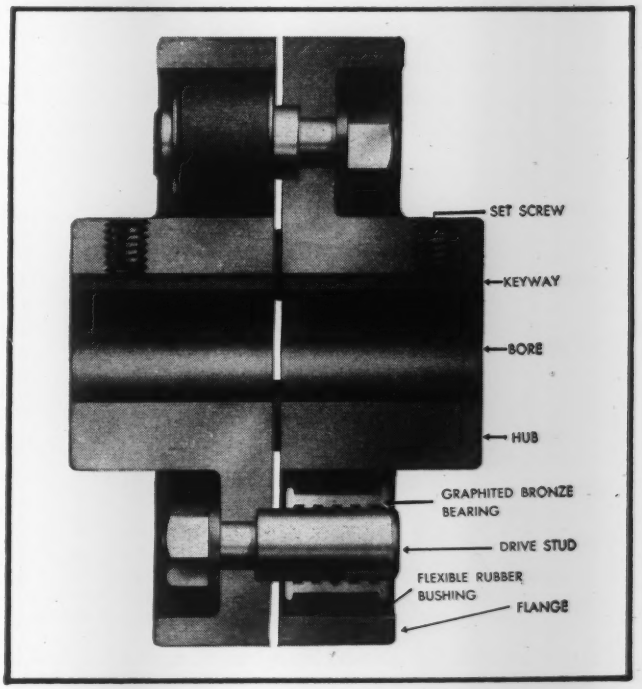
Next, more should be told of Mr. J. P. Henderson and his purpose in appearing in future months. Henderson is a garrulous old timer, a former chief engineer, who prefers to avoid identifying his former business affiliation for what he claims will later prove to be sufficient reason. J. P.'s personality and his background will speak for themselves, we assure you. He modestly claims that his contributions might seem to be nothing new but perhaps will be seen in a



THEY THINK OF

AJAX

as America's standard



● 30 Years of satisfactory performance on direct-connected generators, pumps, compressors, winches, speed reducers and other similar equipment have proved the economy of protecting good machinery with Ajax Flexible Couplings.

They protect bearings, gears, armatures, impellers and other costly working parts against unavoidable angular and offset misalignment.

Ajax Flexible Rubber Bushings provide a quiet, cushioned drive in both directions of rotation.

Ajax oilless bronze bearings are self-lubricated for life.

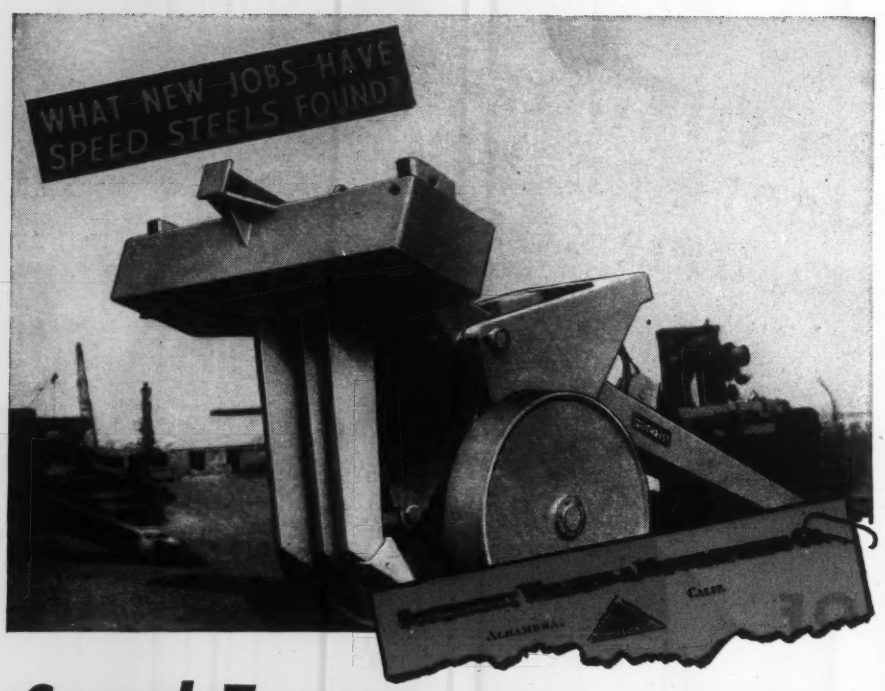
No problems are set up by centrifugal force. They operate successfully in abrasive-laden air. They operate vertically or horizontally.

Free end float lets electrical machinery find its magnetic center without interference.

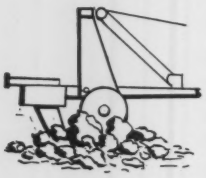
Standard Ajax Couplings are made of forged steel or cast semi-steel. Aluminum, bronze and other metals available for special applications. Made in a wide range of sizes and capacities...write for catalog.

AJAX FLEXIBLE COUPLING CO. INC.

WESTFIELD, NEW YORK

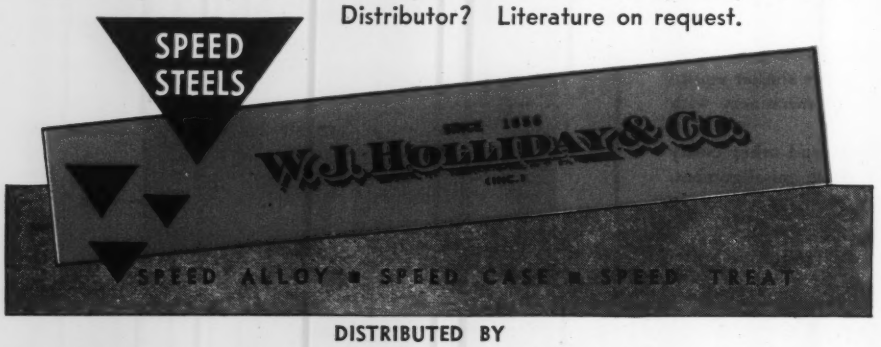


Speed Treat Steel Gives Powerful Brute A Tremendous Bite



The big teeth of this Southwest Cable Ripper have to penetrate rock hard surfaces up to 60" deep and withstand tremendous shock loads. A hard-packed airport runway, for example, snapped off ordinary steel shanks like toothpicks. To give this powerful brute teeth with a real bite Southwest is making them of Speed Treat (x1545) Plate Steel.

A tensile strength of 90-100,000 PSI and Brinell hardness of 156-196 imparts exceptional ruggedness and wearability to these vital components. Speed Treat is a versatile steel, too. Its unusual machinability plus its high physical properties, imparted by its .45% carbon and 1.25% manganese content, have won industry's favor for mechanical rubber molds, flame or induction hardened gears, sprockets, cams, eccentrics, cylinder bearers and countless other items, where machinability, finish, tool life and hardenability are important factors. Chances are you can improve your own product and save money with Speed Treat. Why not talk it over with your Speed Steel Distributor? Literature on request.



DISTRIBUTED BY

Brown-Wales Co., Boston-Hartford-Lewiston, ■ Bridgeport Steel Co., Bridgeport, Conn. Beals, McCarthy & Rogers, Buffalo, N. Y. ■ Burger Iron Co., Akron, Ohio ■ Grammer, Dempsey & Hudson, Inc., Newark, N. J. ■ Earle M. Jorgensen Co., Los Angeles-Houston-Oakland-Dallas ■ Passaic County Steel Service, Inc., Paterson, N. J. ■ Peckover's Ltd., Halifax-Montreal-Toronto-Winnipeg-Vancouver ■ Peninsular Steel Co., Detroit, Mich. Pidgeon-Thomas Iron Co., Memphis, Tenn. ■ Horace T. Potts Co., Philadelphia-Baltimore

Produced by W. J. Holliday & Co., Inc., Speed Steel Plate Division, Hammond, Indiana. Plants: Hammond and Indianapolis, Indiana

different light or serve as a reminder of the self evident.

His own forecast of his future contributions follows:

For many years I hired engineers, draftsmen, checkers, detailers, and stenographers—and then had to live with the results. How some of these people looked from the chief engineer's office will be described. Let me set the stage.

All of us as individuals deal with three major elements — things, ideas and people. Things and ideas are paramount in the engineer's mind and work; people are frequently relegated to the realm of the less important. Psychologists have a fancier lingo for it than this, but the field of human activity involving personality, social awareness, human relations, etc., is frequently the arena in which we fail, reach mediocrity, or achieve success—even as engineers. An old story, isn't it?

Certain classifications into which most technical people fall take on very clear forms in the eye of an engineering manager. It seems many of the innate quirks of personal make-up that lead a man into engineering work can, at one and the same time, underwrite his technical prowess as well as his personal failure. These qualities, of different sorts in these various groups of engineers, are often accentuated in the technical environment. The salesman is a good case in contrast; his rough edges in human relations are knocked off quickly—or he doesn't eat.

Thus, among engineers there so frequently develops a rugged individualism. Accept it from one who's worked with many, they can be hard to take. In fact, the engineering manager must take them—and often, I think, he can credit a major portion of his salary to the blending of diverse and often perverse human characteristics.

Labels are easy to find—the detail engineer, the closet engineer, the problem man, the huddle type, etc. As I bring these classifications into focus in future months, many engineers will see some people they know, I'll guarantee.

J. P. H.

Look for Henderson's critical appraisal of the detail engineer next month.

REPORT ON

Materials

HIGH optimism is the keynote of most recent discussions of materials availability by both industry and government observers. At first the "big pinch" on materials was forecast by government officials for 1953 and then, in rapid succession, for late 1952 and the second quarter of 1952. Now it seems that the worst situation is over.

Many explanations have been offered for the sudden relaxation. One is the slowing-down of military rearmament schedules, including the aircraft program. Another is the prolonged lull in consumer buying. A third viewpoint is that military departments, traditionally liberal in figuring their needs, ordered critical materials far in excess of actual requirements. A fourth, and quite likely, opinion is that the whole situation is purely psychological; that scare buying and padded materials requirements, caused by gloomy Washington predictions of shortages and inflationary buying, are now disappearing.

Whatever the cause, it is certain that the Defense Production Administration will proceed slowly and cautiously on decontrols. There *are* surpluses, but many materials are just as critical now as they were six months ago.

The brightest outlook appears to be in steel and aluminum. Unprecedented production figures reached by steel during the past year, and actual and projected expansions in productive capacity for both steel and aluminum, have led to surpluses and unbridled optimism for the future. Although shortages of many types of aluminum and steel exist, some Washington planners are privately predicting the end of all controls on these two metals by December 31. Copper and nickel will probably have to wait longer, since current supplies are still short and proposed expansion only moderate.

Recent Decontrols: Leather and polytetrafluorethylene (Teflon) have been added to the list of seven

WHY NOT
cast a
magnesium
mousetrap?

Maybe it IS a lousy idea . . .

On the other hand, maybe it's as practical as using cheese for bait.

Frankly, we haven't gotten out a slide rule or put our thinking cap on tight, to figure it out one way or the other. Maybe the mice wouldn't go for it.

But we do know a lot of things WILL be cast in magnesium or aluminum after military requirements are satisfied.

A lot of things no one ever thought would be.

So whatever your plans are; whatever directions they might take; whatever products you might have on scraps of paper, in preliminary drawings, or just plain ideas-on-the-brain . . . . keep an open mind in terms of magnesium or aluminum in sand-cast, semi-permanent or permanent mold form.

Particularly Well-Cast castings.

Naturally.

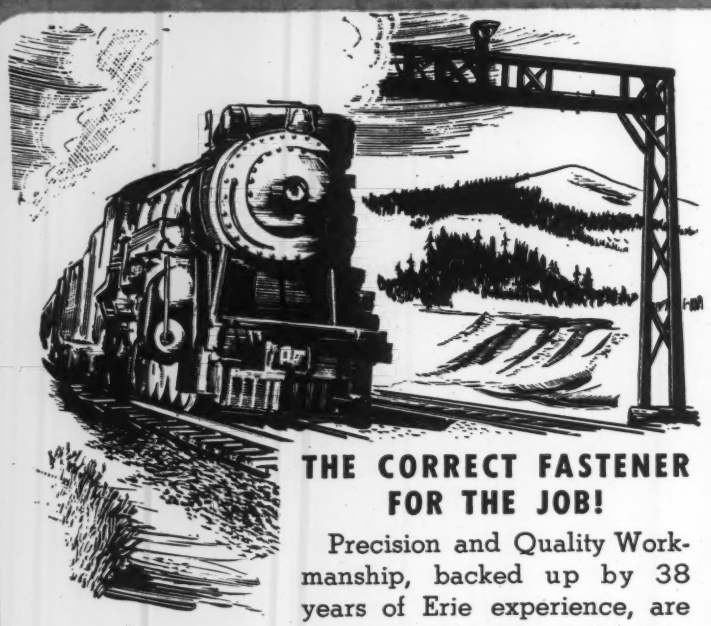
Well-Made Wood and Metal Patterns • Ampco Bronze Castings

Almost a half-century of Experience

THE WELLMAN BRONZE & ALUMINUM CO.

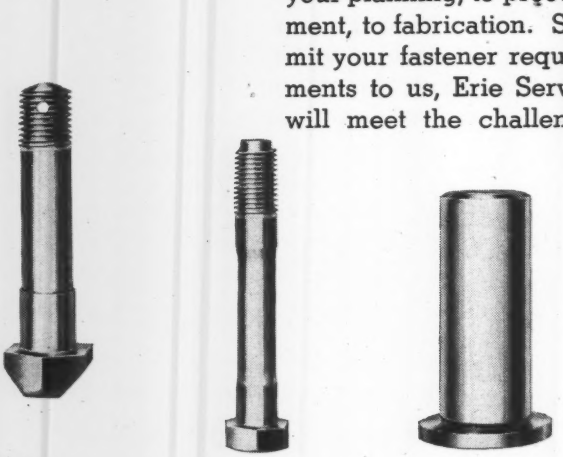
DEPT. 10 12800 SHAKER BLVD., CLEVELAND 20, OHIO

For DEPENDABILITY IN RAILROAD EQUIPMENT



THE CORRECT FASTENER FOR THE JOB!

Precision and Quality Workmanship, backed up by 38 years of Erie experience, are yours for thoughtful buying. Whether you require a fastener made from carbon, alloy or stainless steels, to special design, to exacting specifications, Erie fasteners will save you time and expense . . . from your planning, to procurement, to fabrication. Submit your fastener requirements to us, Erie Service will meet the challenge.



A SUBSIDIARY OF Barium STEEL CORPORATION Steelwright to the Nation

ERIE BOLT and NUT CO.

ERIE • PENNSYLVANIA

STUDS • BOLTS • NUTS
ALLOYS • STAINLESS
CARBON • BRONZE

Representatives in Principal Cities.

materials released from government controls (March, Page 202). Government restrictions on the use of lead have also been completely eliminated. Manufacturers must, however, continue to report their usage of these materials.

Several plastics stand a good chance of being removed from controls within the next few months, with polyethylene probably leading the parade. NPA has already stated that decontrol action on this plastic is possible by the end of the third quarter in view of increased supplies.

Cold-rolled sheet and strip, secondary tin-mill products, small-diameter merchant pipe and merchant wire are also likely candidates. These steel products are already being considered for decontrol, according to NPA. But NPA also says it will proceed slowly, and that any decontrol plan would probably be limited so that CMP allotments would be filled first.

Another healthy sign is the recent return of rubber procurement authority to private industry. The U. S. rubber stockpile has now reached "safe levels," according to Jess Larson, General Services Administrator, so that "the conditions which impelled the Government to act as exclusive buyer and importer no longer exist."

List of Basic Materials: In the NPA, *List of Basic Materials and Alternates,* released on March 3, a few metals and chemicals have eased, but there is little movement in other materials groups. Steel plates, hot-rolled alloy bars and zinc have been removed from the "most critical" category, although cold-drawn and hot-rolled carbon bars have been added.

The following partial list supersedes the one published in MACHINE DESIGN, February, Page 230.

Metals—Group I-A
(In Short Supply)

a—Nonferrous:
- *Aluminum
- *Beryllium
- *Copper
- Magnesium
- *Selenium
- Titanium
- *Tin
- Zinc

b—Precious:
- Iridium
- Osmium
- *Platinum

c—Ferrous alloying elements:
- *Cobalt
- *Columbium

*Most critical

(*Continued on Page* 266)

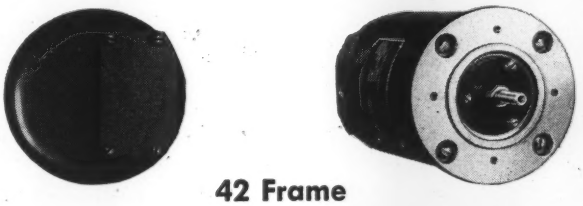
DOERR MOTORS

THE RIGHT ANSWER TO MANY DESIGN PROBLEMS

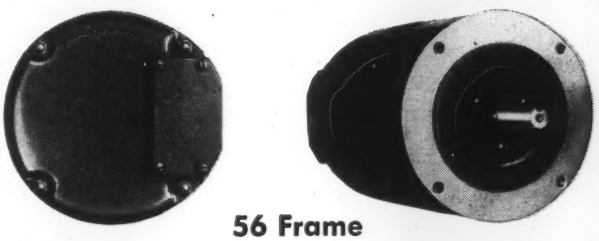
A versatile line of high quality, precision made motors in ratings from 1/30 to 5 horsepower, used by leading equipment manufacturers on a growing list of applications.

The large number of special types now in production permits the adaptation of present castings, windings and mountings to meet new design problems at a minimum of expense.

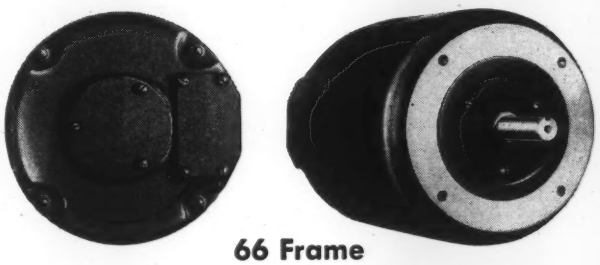
NEMA Standardized Type C Face Mountings



42 Frame

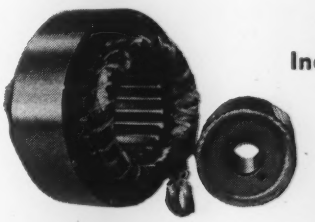


56 Frame

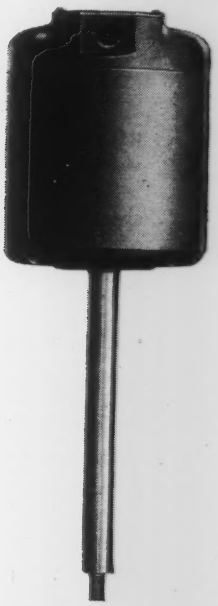


66 Frame

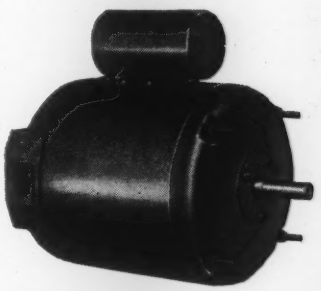
We Welcome a Chance to Give You More Details on These Motors



Motor Parts for Industrial Oil Burners



Long Shaft Motor used for Coolant and Air Conditioning Circulating Pumps



Two-speed Exhaust Fan Motor

DOERR

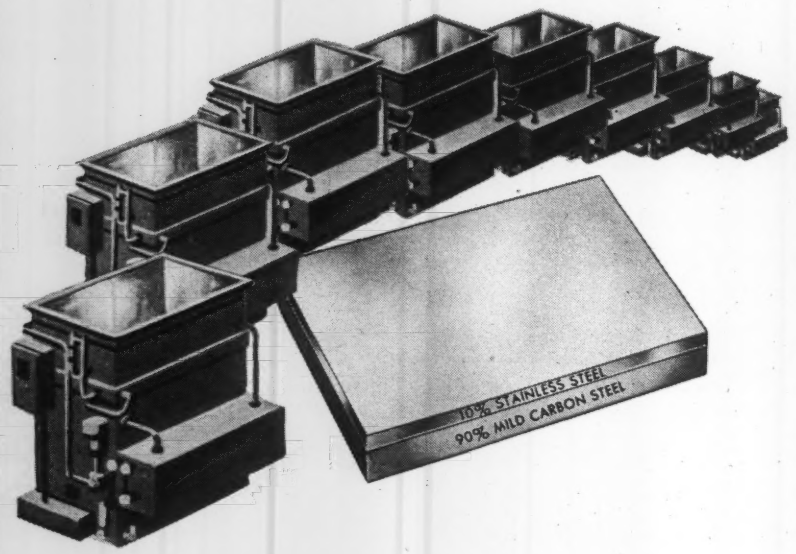
Electric Corp.

ELECTRO MACHINES, INC.

90 North Third Avenue
Cedarburg, Wisconsin

How to Make Stainless Protection Go NINE TIMES FURTHER... with PERMACLAD

STAINLESS CLAD STEEL



Want stainless protection for your product or equipment—without wasting stainless steel? You'll get it at low cost—with PERMACLAD!

A 10% layer of stainless, inseparably welded to a 90% mild steel backing, gives PERMACLAD the surface characteristics of solid stainless *and* the easy forming qualities of carbon steel. This means real savings in corrosion resistance and in fabrication as well. For you can cold-form PERMACLAD with ease, draw it deeper without intermediate annealing, actually form it into products impossible with many other materials.

Even with the most severe draw, the percentage of cladding (which can be 20% or more if desired) never varies. And the stainless layer remains inseparably welded to its backing. For gleaming, stainless products and corrosion resistant equipment, design and build with PERMACLAD. The coupon below brings you full details in our new 8-page folder (P-98).

Send for Free Folder Today

FOR BETTER PRODUCTS AT LOW COST . . . SPECIFY PERMACLAD

ALAN WOOD STEEL CO. ESTABLISHED A.W. 1826 CONSHOHOCKEN, PA.

PERMACLAD

STAINLESS CLAD STEEL

STEEL SCRAP FIGHTS FOR DEFENSE. SELL YOUR SCRAP NOW!

ALAN WOOD STEEL COMPANY Conshohocken, Pa.

Over 125 Years of Iron and Steel Making Experience

Gentlemen:
I am interested in stainless protection with PERMACLAD.
Please send me full information and new, free folder (P-98).

Name _____ *Title* _____

Company _____

Address _____ *City* _____ *State* _____

Other Products: A.W. ALGRIP ABRASIVE Floor Plate • A.W. SUPER-DIAMOND Floor Plate • Plates • Sheets • Strip • (Alloy and Special Grades)

(*Continued from Page* 262)

*Molybdenum
*Nickel
*Tantalum
*Tungsten
Vanadium

d—Ferrous:

Bars, cold drawn:
*Alloy
*Carbon steel
Bars and semifinished, hot-rolled:
Alloy
*Carbon steel
Castings:
Carbon steel
Gray iron: Heavy, over 3,000 pounds
Gray iron alloy: Heavy, over 3,000 pounds
Steel, high alloy:
Corrosive-resistant
*Heat-resistant
Die blocks
Forgings, heavy
Iron powder
Pig iron, low phosphorus
Pipe:
Seamless, all sizes
Welded:
4 inches and over
3 inches and under, galvanized
Plate, tin
Plates
Rails
Rope wire, galvanized
*Shapes, structural
Sheet, galvanized
Strand wire, galvanized
*Stainless steel: Nickel-bearing
*Tubing, seamless:
Alloy mechanical
Alloy pressure
Carbon, mechanical
Carbon, pressure
Wire, drawn: welding quality

Metals—Group II-A
(In approximate balance)

a—Nonferrous:

Antimony
Calcium
Germanium
Lead

b—Precious:

None

c—Ferrous alloying elements:

Chromium
Manganese
Silicon

d—Ferrous:

Forgings, medium
Pipe welded: 3 inches and under (except galvanized)
Pig iron (other than in Group I)
Sheet: Hot rolled
Strip: Hot rolled

Metals—Group III-A
(In fair to good supply)

a—Nonferrous:

Bismuth
Cadmium
Mercury

b—Precious:

Gold
Palladium
Rhodium
Ruthenium
Silver

c—Ferrous alloying elements:

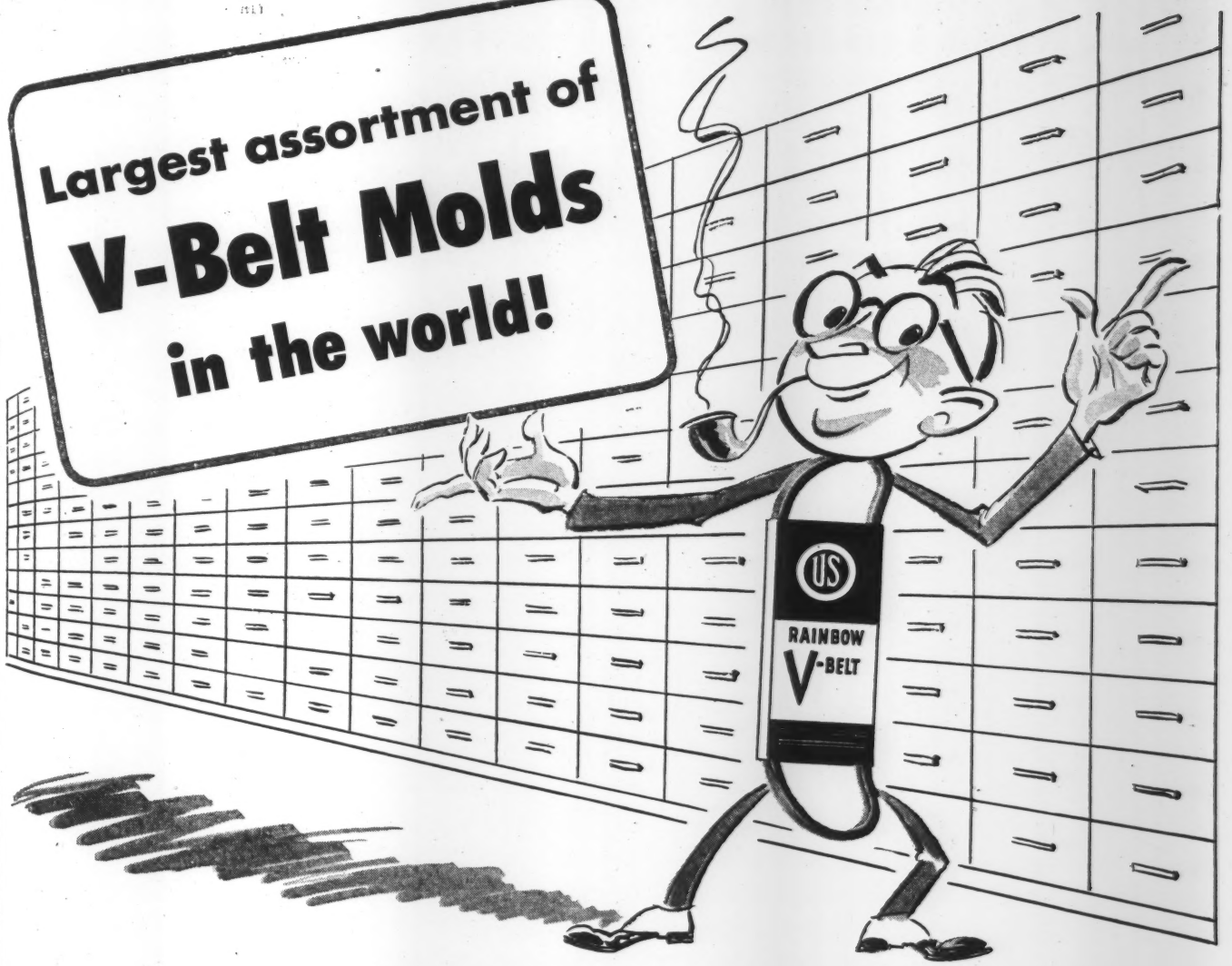
Boron
Tellurium
Zirconium

d—Ferrous:

Castings:
Gray iron alloy, light-weights
Gray iron (light and intermediate weights)
Iron malleable
Forgings, small
Sheet: Cold rolled
Stainless steel: Straight chrome
Strip: Cold rolled
Tool steel
Tubing, welded: Carbon, mechanical
Wire, drawn (except welding quality)

*Most critical

Largest assortment of V-Belt Molds in the world!

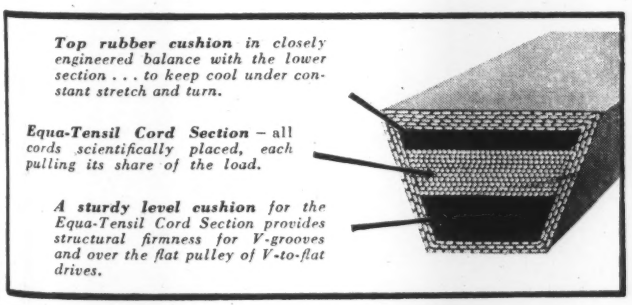


THAT'S WHY, if you want a "special" in a hurry, a U. S. Rubber belt usually can be obtained without making a new mold. You get the fastest possible delivery of your specific belt.

"U. S." engineers will compound belts with special properties to withstand conditions not usually found on the average drive—oil, high temperatures, generation of static electricity, to name but a few.

"U. S." V-Belts have practically no stretch. Before leaving the factory, the inherent stretch has been worked out by mechanical means. But sufficient elasticity is retained to enable the belts to withstand severe shock loads. Extra pulling power is gained by means of straight sidewalls, which grip the grooves for complete contact the full height of the belt. Protective jackets increase the grip while keeping out the dirt and prolonging life.

Finally, each belt has the unique U. S. Rubber development which provides efficient pull and strength for diverse operations—the famous Equa-Tensil Cord Section. Order from your jobber, or for more information, write to address below.



***Top rubber cushion** in closely engineered balance with the lower section . . . to keep cool under constant stretch and turn.*

***Equa-Tensil Cord Section** – all cords scientifically placed, each pulling its share of the load.*

***A sturdy level cushion** for the Equa-Tensil Cord Section provides structural firmness for V-grooves and over the flat pulley of V-to-flat drives.*

A COMPLETE DRIVE SERVICE

MULTIPLE V-BELTS

F. H. P. BELTS • SHEAVES

FLAT BELTING AND BELTING

SPECIAL PURPOSE BELTS

PRODUCTS OF

U.S.RUBBER

SERVING THROUGH SCIENCE

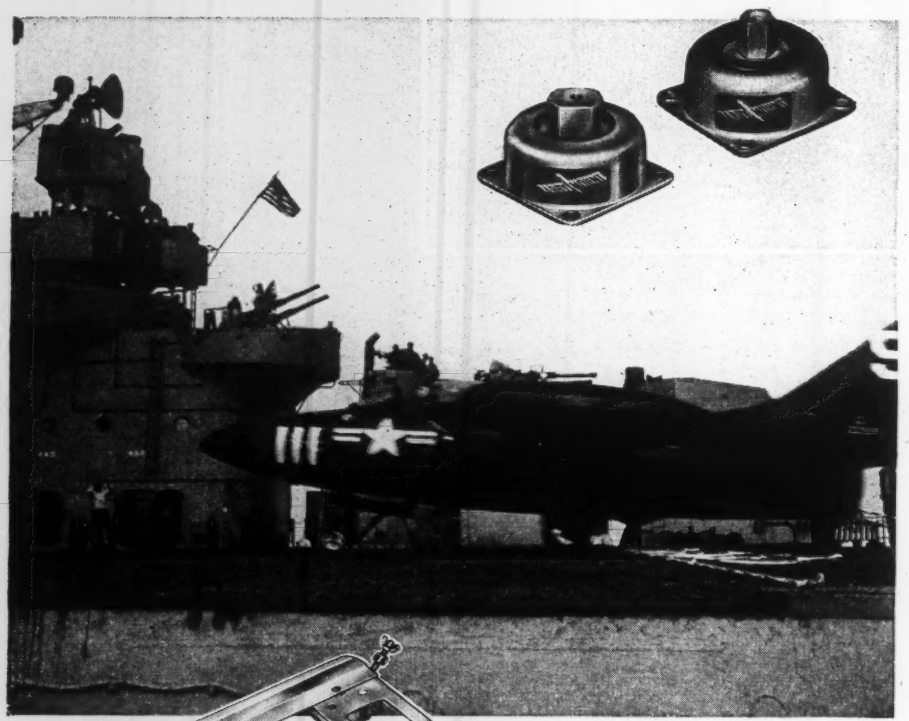
UNITED STATES RUBBER COMPANY

MECHANICAL GOODS DIVISION • ROCKEFELLER CENTER, NEW YORK 20, N. Y.

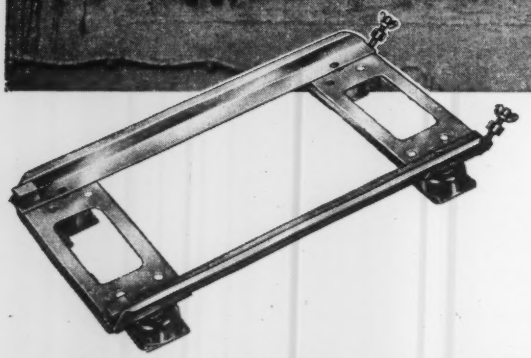
SHOCK and VIBRATION NEWS

BARRYMOUNTS FOR ASSURED CONTROL OF SHOCK AND VIBRATION

can YOUR equipment stand the shock of carrier landings? Barrymounts can!



Official United States Navy Photograph



New military specifications for all services require ruggedization of your equipments with their mountings.

Ruggedized Air-damped and All-Metl Barrymounts and mounting bases are now available to meet the shock test requirements of specifications MIL-T-5422 (Aer), MIL-E-5272 (USAF), and AN-E-19. These mountings hold your equipment securely and maintain uniform performance characteristics even after the repeated shock of many aircraft carrier landings.

For full information about Barrymounts and bases, write today for your free copy of each of these Barry catalogs:

Catalog #524—Ruggedized Barrymounts and ruggedized mounting bases.

Catalog #523—Air-damped Barrymounts and mounting bases.

Catalog #509—All-Metl Barrymounts and mounting bases.

THE **BARRY** CORP.

722 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

SALES REPRESENTATIVES IN

Atlanta Chicago Cleveland Dallas Dayton Detroit Los Angeles Minneapolis New York Philadelphia Phoenix Rochester St. Louis San Francisco Seattle Toronto Washington

Chemicals—Group I-B
(In short supply)

Alkyl phenols
*Alkyl polysulfide polymers
Butadiene
Polyethylene resins
Selenium compounds
Styrene

Chemicals—Group II-B
(In approximate balance)

Alkyd resins
Carbon black
Cellophane
Melamine resins
Monochlortrifluorethylene
Phenolic resins
Polyester resins
Polytetrafluorethylene (Teflon)

Chemicals—Group III-B
(In fair to good supply)

Cellulose acetate
Cellulose butyrate
Ethyl cellulose
Methacrylate
Nylon, plastic type
Polystyrene
Polyvinyl acetate
Polyvinyl alcohol
Polyvinyl butyral
Polyvinyl chloride
Urea resins

Miscellaneous—Group I-E
(In short supply)

Asbestos:
  Chrysotile: Crude and spinning fibers
  Shingle fibers
  Amosite
Graphite, natural:
  Crucible flake
  Ceylon: High carbon amorphous lump
Mica:
  Muscovite block and film, stained and better
  Bookform splittings
Rare earths
Rubber:
  Butyl (GRI)
  Natural, dry
Talc, Indian block, lava grade

Miscellaneous—Group II-E
(In approximate balance)

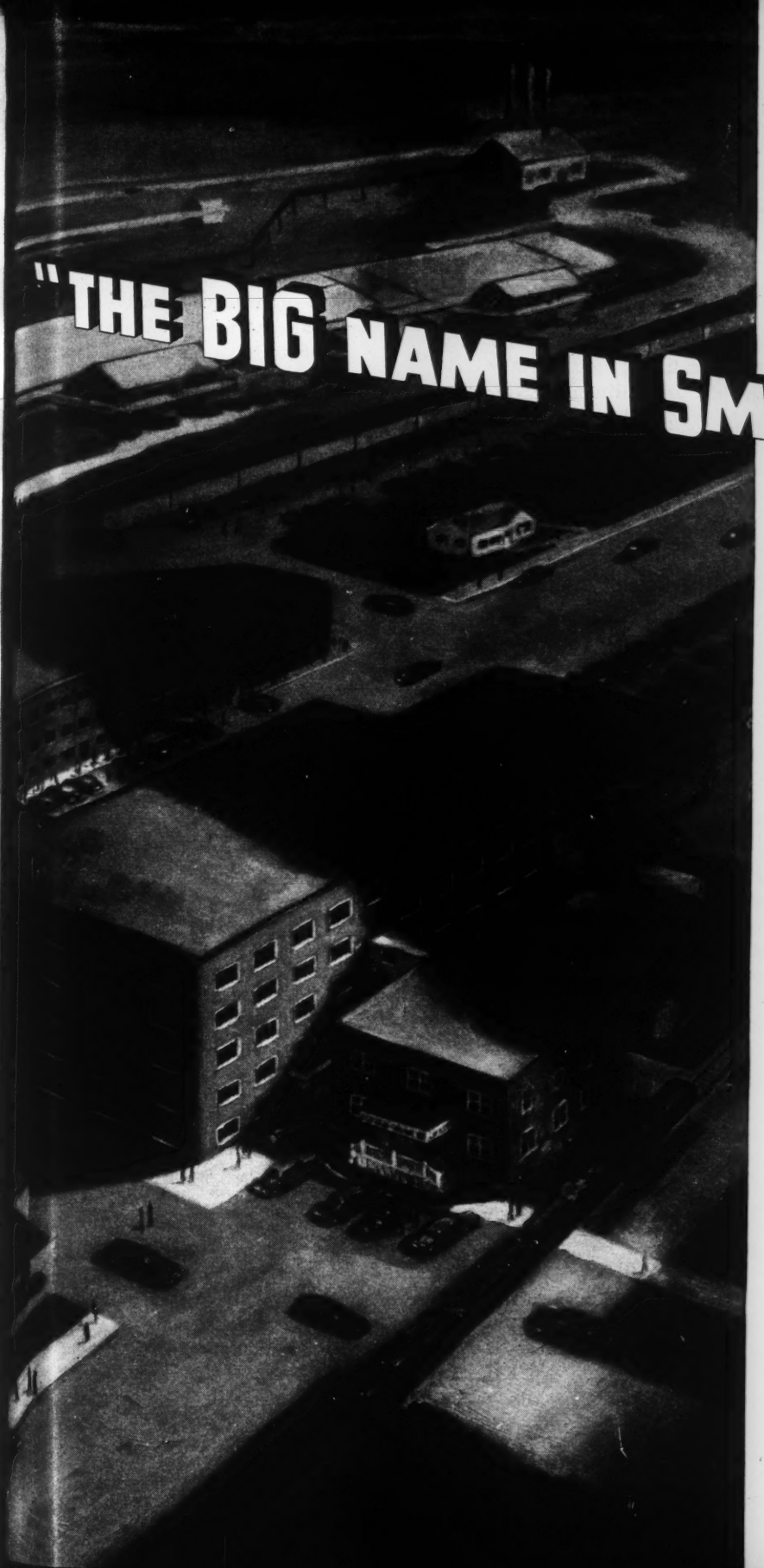
Abrasives, synthetic:
  Aluminum oxide
  Silicon carbide
Corundum
Graphite, artificial: Electrodes, anodes and special shapes
Mica:
  Phlogopite, splittings
  Muscovite block and film (lower than stained)
  Muscovite splittings, loose
Paper
Paperboard
Quartz crystals (MBS Grades I and II)
Rubber: Synthetic (GRS)
Talc: Ground, including steatite

Miscellaneous—Group III-E
(In fair to good supply)

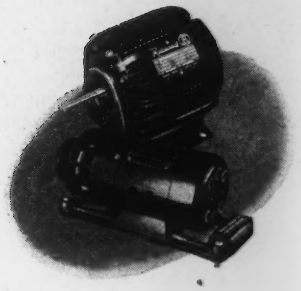
Asbestos, chrysotile: Shorts and waste fibers
Rubber:
  Reclaimed
  Natural, latex

*Most critical

Copies of the latest *List of Basic Materials and Alternates* may be obtained from the nearest district or regional office of the Department of Commerce or by writing Printing Services, Department of Commerce, Washington 25, D. C.



"THE BIG NAME IN SMALL MOTORS"



and Manufacturers of Special Equipment for Defense Requirements

The multi-plant operations of the dynamic Redmond organization — in Michigan, Arkansas and Canada—serve you just as though they were the electric motor division of your own organization.

Every year these efficient plants turn out millions of low-range fractional horsepower Redmond Micromotors, in sizes up to 1/10th horsepower, and blowers up to 220 cubic feet per minute output.

For defense requirements, too, Redmond is again ready with the experience to engineer and mass produce precision dynamotors and a variety of other equipment.

When you need quality in quantity, call first on Redmond, the BIG name in Small Motors.

REDMOND COMPANY, INC., Owosso, Mich., U.S.A.
INDUCTION MOTOR SALES OFFICES: *Eastern Area: 420 Lexington Ave, New York 17, N.Y.; Central Area: Owosso, Michigan; Midwest Area: 332 S. Michigan, Chicago 4, Ill.; Southwest Area: 1330 N. Industrial Blvd., Dallas, Texas; Western Area: (Redmond Company of Calif., Inc.) 1260 S. Boyle Ave., Los Angeles 23, Calif.* **SERIES MOTOR SALES OFFICES:** *Owosso, Mich.* **OVERSEAS SALES OFFICES:** *420 Lexington Ave., New York 17, N.Y., cable address, REDISINC-NEW YORK.*

MICROMOTORS

PUMPS

FOR COOLANTS, LUBRICANTS, AND ABRASIVE LIQUIDS

PUMPS

POSITIVE DISPLACEMENT AND IMPELLER TYPES

PUMPS

J. I. C. STANDARDS OR DIRECT MOTOR CONNECTED

PUMPS

DEPENDABLE, ECONOMICAL, EFFICIENT

STANDARD OR SPECIAL, FOR EVERY MACHINE TOOL AND INDUSTRIAL USE

Rollway PUMPS

Pioneer PUMP

& MANUFACTURING CO., INC.

19652 JOHN R STREET
DETROIT 3, MICHIGAN

WRITE FOR CATALOG

Design Abstracts

(*Continued from Page* 213)

dynamic-dynamic design aspects are essentially the same.

The speed of operation of a free piston engine in cycles per minute is determined by the mass of the piston assembly and the character of the non-linear "gas springs." Because of this nonlinearity, the speed must be established from successive numerical or graphical integrations starting from the differential equation of motion and a resultant force versus piston displacement characteristics established from indicator cards for each cylinder. Thus, for a given gas generator assembly, geometry (which fixes the mass), delivery rate, pressure, and temperature of the turbine gas is determined and the turbine power can then be calculated. If turbine output does not correspond to the desired rating, it is possible to scale the generator geometry up or down to provide the necessary delivery rate.

From a paper entitled, "The Free-Piston Engine Development—Present Status and Design Aspects," presented at the ASME Spring Meeting in 1952.

Power Steering in 1952

By W. K. Creson

Ross Gear and Tool Co.
Lafayette, Ind.

POWER steering currently is playing a dramatic role in car and truck design. On cars, it was original equipment on one make in 1951; in 1952 it is expected to be on at least five. On trucks, it has been applied heretofore to rugged, off-the-road equipment, but 1952 bids to extend its use, in far greater volume, to operations on the highway and thereby permit greater pay loads while staying within legal axle loading. Over-all production of power steering for cars and trucks goes something like 10,000 for 1950, 40,000 for 1951, and over 200,000 for 1952. Further rapid growth of power steering is indicated because it lightens work, contributes to safety, and especially because its major technical problems, including cost, are yielding to years of testing and development.

Parking conditions in modern cities and towns have long called for power steering on cars. It has more to offer the car driver, however, than extremely easy parking. Those who have used it on long mileages, in mountain country and rough roads, report less fatigue and a feeling of greater confidence in control. Obstructions, chuckholes, and tire blowouts which can cause loss of control without power steering are negotiated with a higher degree of safety. The quicker steering response which goes with power steering is useful in avoiding collisions and in recovering from skids. In chassis design, greater directional stability can be built in without the traditional penalty of increased steering effort.

New Applications Foreseen

The present adoption of power steering on passenger cars is interesting not only to the car engineer but also to the designer of any wheeled vehicle. Passenger car production and design techniques, and passenger car volume, offer many opportunities to reduce costs. A significant cost reduction is just what was needed to bring about broad use of power steering, and it now seems likely that such lower costs are to come. Some of the equipment, designed and produced for cars, can be directly used on small and medium duty trucks, agricultural and industrial equipment. The larger vehicles will, as now, require special sizes in smaller volume, but the designs will be influenced, and their costs affected, by the design and production pattern set for passenger cars. Major maintenance problems are being minimized by careful study and design consideration.

Our patent library contains copies of 270 patents relating to power steering, and there is considerable activity in the art at this time. About half of the patents pertain to fluid power, with the remainder about equally divided between mechanical power take-off and electrical drive. The hydraulic

Baldor

Better MOTORS

EXTRA FEATURES AT NO EXTRA COST...

Totally enclosed . . . ball-bearing.

Externally ventilated, fan-cooled, non-clogging. Dust-proof, splash-proof, lint-proof.

Standard NEMA dimensions.

Corrosion-resistant . . . inside and out. Specially impregnated to resist moisture.

Standard and face mounted end-plates, interchangeable for vertical or bracket type motors.

ASK FOR BULLETIN and mechanical data on our complete line of electric motors (1/20—20 HP).

BALDOR ELECTRIC COMPANY • ST. LOUIS

BAFFLED BY A MATERIAL PROBLEM?

Consider Felt — Miracle Material of a Million Uses

Because of its unbelievable variety of characteristics, **FELTERS FELT** is used in probably every industry and for a literally unknown number of applications.

One list of uses starts with "artificial limbs" and ends with "xylophones"!

We make **FELTERS FELT** so soft you can hardly feel it others hard and tough enough to be skived, ground, turned, chiseled.

What's more, **FELTERS FELT** will not ravel or fray...can be cut with a clean, precise edge.

We can supply you with the exact felt you need in the exact shape, ... size, color, thickness, consistency your specifications demand.

It will pay you to write today.

Fill out and Mail this Coupon TODAY!!

The FELTERS COMPANY

Manufacturers of Unisorb for Machine Mounting

210-MD SOUTH STREET, BOSTON 11, MASS.

Gentlemen: Please send me details on Felters Felt and Felters Precision Cut Felt Parts. I have the following material problem:

.....

.....

.....

Name & Title.....

Company.....

Address.....

City & State.....

devices seem also to have first call as regards equipment now available, or projected for public use in the near future.

Because many years have gone by since the fundamental art was initiated, the validity of basic patent claims has been rather generally annulled by the passing of time. Power steering is a kind of servomechanism which, in fluid power form, might be described, in a generic patent claim, about as follows: A steering device comprising means for manual steering, a fluid motor operatively connected thereto to supplement manual effort, a follow-up valve constantly communicating with said motor to control fluid flow thereto, said valve being exposed to fluid working pressure in such manner that manual steering force is proportional to fluid motor output force.

The devices which are, or soon will be, in production are primarily for application to vehicles which were designed for manual steering. The power steering is not always integrated into the design of these vehicles as a whole, but rather is adapted to them. As power steering comes into more general use, its physical needs and performance will be considered when new chassis characteristics are first formulated. On vehicles having such design treatment, power steering will approach perfection as to performance, freedom from service difficulties, and will be widely used at relatively low cost.

From a paper of the same title presented at the Annual SAE meeting in January, 1952.

Magnetic-Particle Clutch

By P. H. Trickey

Vickers Electric Div.
Vickers Inc.
St. Louis, Mo.

DURING the last three years the magnetic-particle clutch has progressed through development and engineering and the major engineering problems appear to have been solved. There appear to be no inherent design limitations regarding size, and clutches have been developed up

(*Continued on Page* 278)

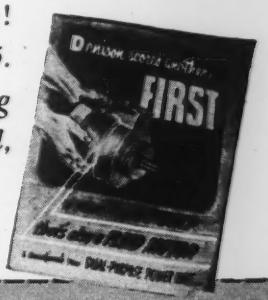
DENISON PUMP/MOTOR

New Dual-Purpose Vane-Type Unit for 2000 psi Continuous Duty

2½ to 70 gpm deliveries as a pump, or torque ratings of 12 to 257 inch-pounds per 100 psi, as a motor

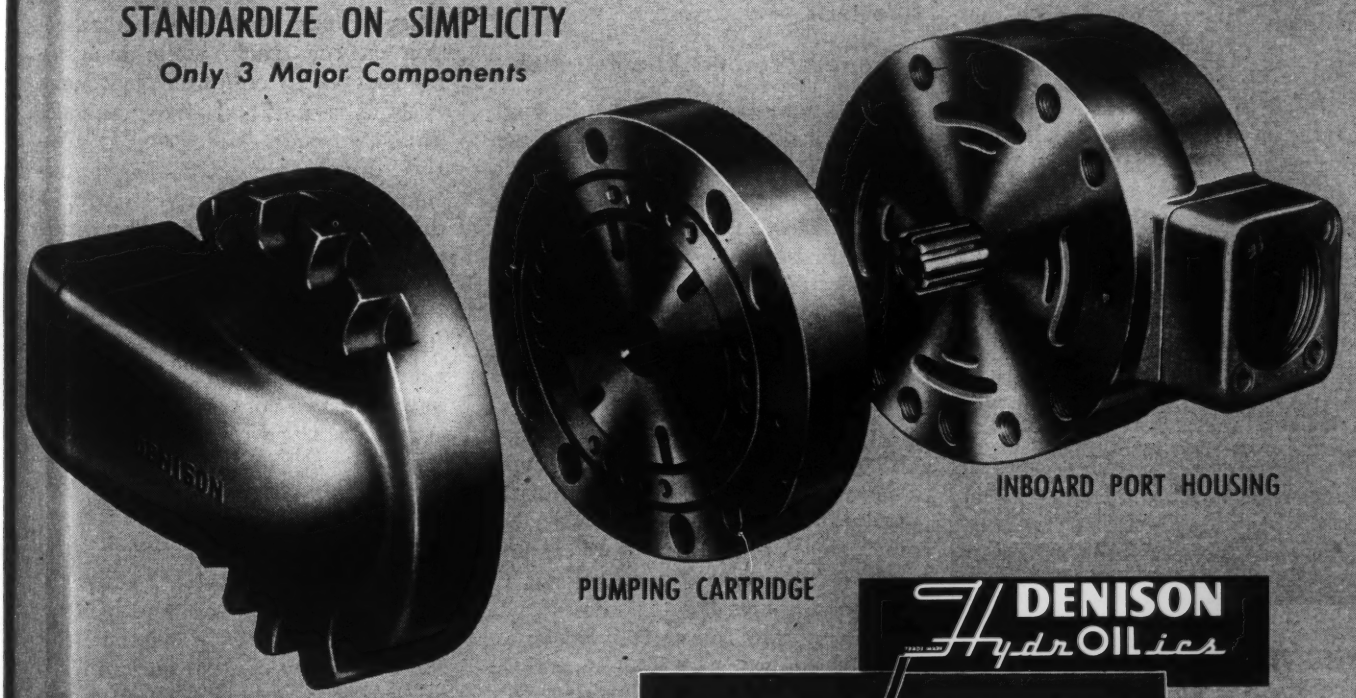
Denison scores a new achievement in dual-purpose pump design. This all-new, vane-type power package is built for *continuous duty* at 2000 psi — and is ready for either pump or motor applications without alterations of any kind! Four sizes are available, with optional cam ring assemblies that permit eleven models, for different pump-volume or motor-torque capacities. Complete hydraulic balance assures longer life through reduced wear. New single stage design and many other features add to the outstanding dual-purpose adaptability of this new Pump/Motor!

Write for Bulletin P-5. The Denison Engineering Co., 1156 Dublin Road, Columbus 16, Ohio.



STANDARDIZE ON SIMPLICITY

Only 3 Major Components



DENISON HydrOILics

PUMP/MOTOR

"The Finest Money Can Buy!"

When it comes to holding the line on costs—and holding strict tolerances at the same time—it takes experience and facilities. For over 86 years, Torrington has been making precision metal parts. Production facilities include batteries of automatic and semi-automatic machines—many of them Torrington-designed—and one of the finest heat-treating departments in the world. In addition, we have at our disposal the combined experience and facilities of all 11 plants of The Torrington Company.

If you need precision metal parts, ask us for a quotation. Just send us a sample or blueprint and tell us how many you need.

THE TORRINGTON COMPANY
Specialty Department
553 Field Street • Torrington, Conn.
Makers of
TORRINGTON NEEDLE BEARINGS

(*Continued from Page 274*)

to several hundred horsepower.

The basic operating part of this clutch consists of two surfaces with the gap between containing finely divided magnetic particles. An electric coil and iron core are so arranged that a magnetic field is set up in the gap. When current flows through the coil the magnetic particles form chains between the surfaces, tending to hold them together. The shear force is approximately proportional to the current.

All of the magnetic-particle clutches have certain features which are very desirable. The first and most unique is the fact that standstill and slipping torques are the same. This eliminates chatter and also allows torques to be set at standstill. Another very important feature is the lack of wear. As far as can be determined, after nearly two years of laboratory and actual service tests, there is no measurable wear on the clutch surfaces and no apparent change in the particle characteristics.

The combination of lack of wear and the absence of levers, pins, toggles, etc., for actuation, provide a clutch that is substantially free of maintenance and adjustment problems.

Output Torque Equals Input

Coil power requirement is very low, on the order of 1/10 to ½ per cent of the shaft power input. This usually amounts to a very few watts of direct current supplied through a small rectifier and transformer from an ac line. Clutch torque is independent of speed and approximately linear in relation to coil current up to saturation of the magnetic circuit parts.

This type of clutch is not a torque converter and has exactly the same torque on both output and input shafts. The power, being the product of torque and speed, is therefore proportional to the shaft speeds. If the speeds differ by two to one, the power in and the power out will also be in the ratio of two to one and the difference will appear as heat in the gap.

These clutches will handle large amounts of power for on-off service and are used for slip service in many cases where control is essential and losses are of secondary consideration. By using proper regulators, the clutches may be used to control torque, or speed, from any signal which can finally be translated into coil current. The response time is short, usually on the order of milliseconds.

From a paper entitled, "The Magnetic-Particle Clutch," presented at the Annual ASME Meeting in 1951.

How to Hunt Ideas

By Alex Osborn
Batten, Barton, Durstine & Osborn, Inc.
New York, N. Y.

THE more ideas we pile up, the more likely we are to hit upon a good idea.

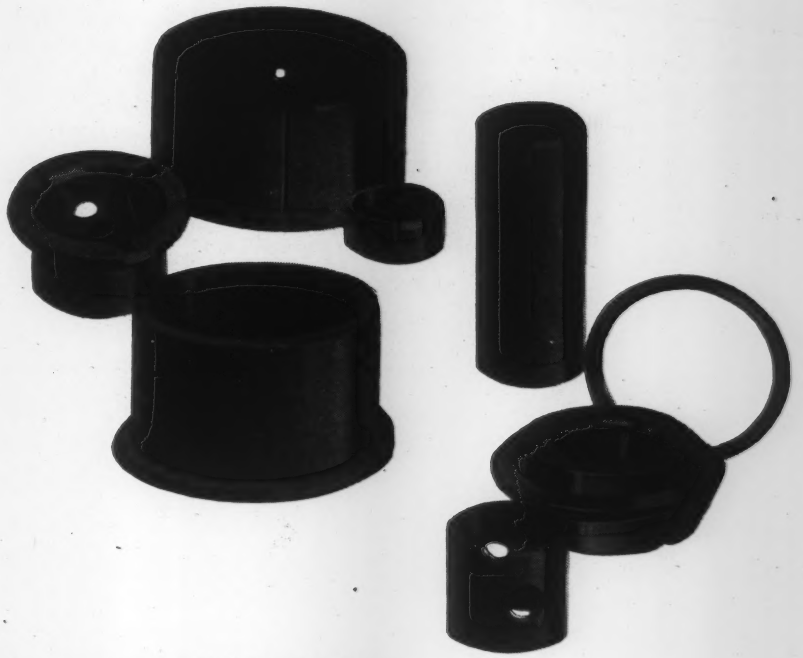
There are ways by which we can make ourselves think up more ideas.

Our mental equipment is made up of *two* thinking minds: (1) a so-called judicial mind, and (2) a creative mind.

By and large, the judicial mind analyzes, compares, and chooses; while the creative mind visualizes, foresees, and generates ideas. These two minds complement each other. Judgment keeps imagination on the track, while imagination serves to enlighten judgment.

Creative ability is likewise made up of two main elements: (1) creative talent—our gift of imagination—and (2) creative effort—a driving force that is often automatic, but which (to a large degree) is subject to our wills. Although some hold that creative power depends almost solely on talent, the weight of the evidence supports the conclusion of Brooks Atkinson who said, "It is the driving force of creativity which is so remarkably unequal—not the degree of native talent."

The drive that makes us get the most out of our talent, is a mixture of inner urges and self-imposed spurs. We all admit that we can easily control our minds in non-creative ways. We could even make ourselves say the Lord's Prayer in the middle of Times Square on New Year's Eve. As Arnold Bennett said, "We can



Rolled bronze bushings, cast bronze bushings and precision bronze parts, produced in hundreds of designs, to many alloy specifications and in a great range of sizes.

Use our specialized facilities—capacity now available.

FEDERAL-MOGUL

FEDERAL-MOGUL CORPORATION, 11045 SHOEMAKER, DETROIT 13, MICHIGAN

FEDERAL Mogul SINCE 1899

Courtesy Bell Aircraft Co., Buffalo, N. Y.

The use and value of S.S.White flexible shafts in driving parts and accessories is amply demonstrated in the crop-dusting helicopter shown above. The shaft transmits power from the accessory gear box to an impeller-type pump which is used to drive insecticide to the spray nozzles . . . a simple, effective way to do the job.

These useful S.S.White "Metal Muscles" are ideally suited to any application in which a rotary power drive or a remote control linkage has to be established between two points. Their simplicity and adaptability to crowded space conditions and varying contours—and the ease with which they can be installed—will make many design and production procedures less complicated.

FLEXIBLE SHAFT FACTS FOR YOU!

This 256-page Flexible Shaft Handbook has complete, authoritative information on flexible shaft construction, selection and application. Copy sent free if you write for it on your business letterhead and mention your position.

THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.
Dept. 4, 10 East 40th St.
NEW YORK 16, N. Y.

Western District Office · Times Building, Long Beach, California

tyrannize over our minds every hour and in no matter what place" —but not without conscious effort can we drive our imaginations.

One basic technique for getting the most out of our imaginations is to ask ourselves certain questions—mainly by way of "what-else?" and "how-else?" By bombarding ourselves with such queries we can pile up a quantity of ore in the form of all kinds of ideas; good, bad, and indifferent. Out of that ore, our own judgment, or the judgment of others, can refine gold—gold in the form of ideas.

Creative Barriers: With most of us, our creative talent has been stifled by ourselves as well as by others. Nearly all of us have built up habits which tend to block our creative power. Some of the self-imposed barriers are:

NEGATIVITY: This tendency is to discourage oneself with adverse criticism, too much and too soon. Creative thinking calls for a positive attitude — a reaction of: "That's good! Now let's think up something better,"—instead of: "No, that won't work. What's the use of trying?"

Confidence Overcomes Fear

FAILURE-PHOBIA: The fear of defeat is likewise a handicap to creativity. In the arena of ideas, we have to laugh off our knockdowns—we have to turn our knockouts into comebacks.

PERFECTIONISM: Creative thinkers have to beware lest excessive perfectionism abort their effort. Edison's first lamp was a crude affair. He could have hung onto his imperfect model while he tried and tried to make it better. Or he could have junked the whole idea. He didn't do either. His first electric lamps were better than candles, kerosene lamps, or gas-lights, so he introduced them. Then he went to work on improvements.

TIMIDITY: This is the most common handicap to creativity. Sometimes it stems from false dignity—the fear lest one look foolish. Most often the cause is lack of confidence—an honest skepticism as to one's ability to think up anything worth while. Here is where we should heed Shakespeare's warn-

(*Continued on Page* 284)

Case History M-112

Here's what we mean by SUPERIOR ENGINEERED FOUNDRY PRODUCTS...

PROBLEM:

1. This 7-ounce malleable iron casting, part of a tube flaring tool, failed frequently in service.

2. The problem was one of design as the metal proved to be clean, sound and of correct analysis.

SOLUTION:

A SUPERIOR FOUNDRY ENGINEERED DESIGN casting in malleable iron . . . result of evaluating the findings of Superior's stress analysis laboratory.

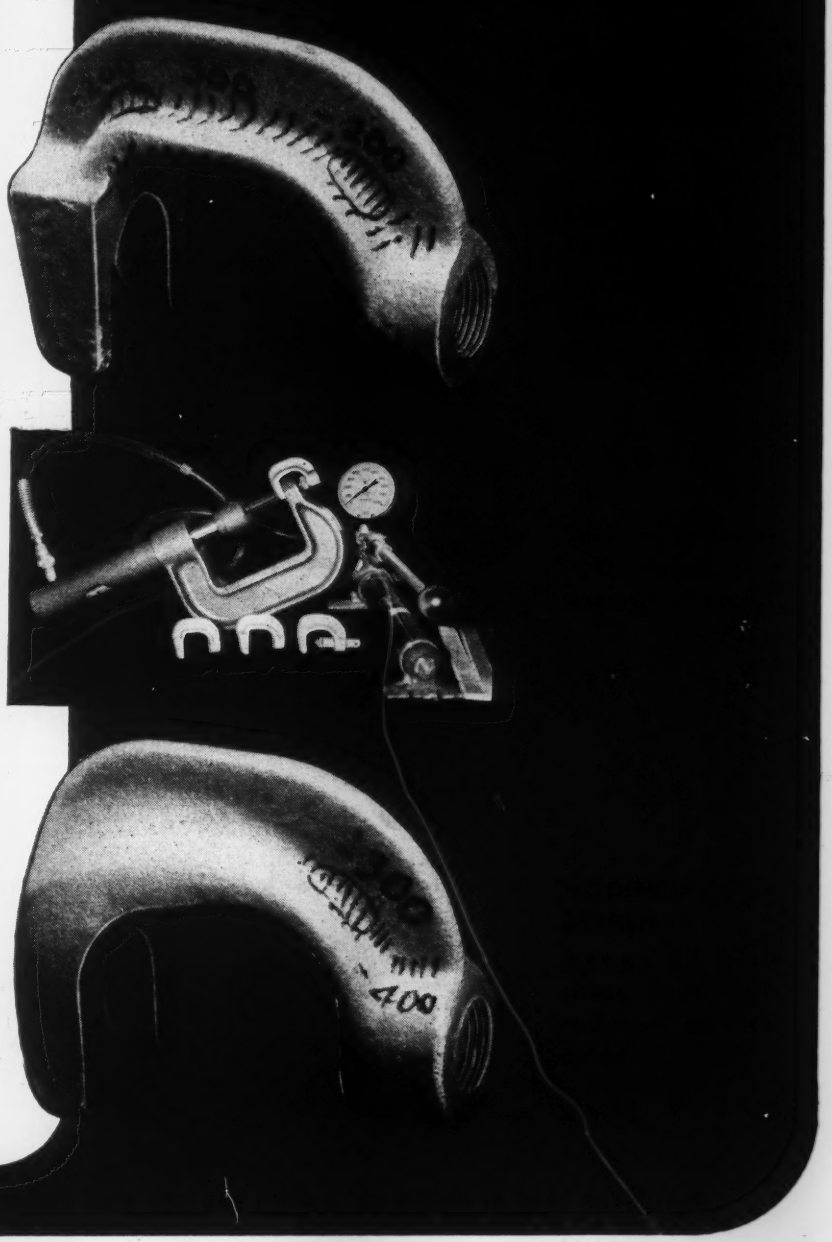
RESULT:

1. Reduction of high stress areas by 33.3% eliminated service failures.

2. Development of new design and gating permitted the best foundry procedure and assured clean, sound castings.

You, too, can get advantages like these! Consult our PRODUCT DEVELOPMENT SECTION regarding your problem.

Make your parts Superior Engineered Foundry Products . . . malleable iron castings to 300 pounds . . . steel castings to 30,000 pounds.



Since 1916

SUPERIOR STEEL AND MALLEABLE CASTINGS CO.

BENTON HARBOR, MICHIGAN, U.S.A.

TO KEEP YOUR CASTINGS COMING . . . KEEP YOUR SCRAP GOING TO THE FOUNDRIES

Above — Oil-less Model 1550 — 8 to 10 C.F.M.
Right — Oil-less Model 3040, end plate removed. From 17 to 24 C.F.M.

Three things about these pumps are outstanding:

FIRST — They run *entirely without oil* in the pumping chamber. Four carbon vanes in rotor lubricate themselves — through thousands of hours of operation. Ball bearings are greased and sealed for life. You can *forget* oiling problems!

SECOND — They completely eliminate oil-mist in the air delivered. Used for *both* vacuum and pressure they *can't* contaminate your product or material with oil droplets.

THIRD — They're built with traditional Gast precision — for years of high performance and dependability.

IF THESE QUALITIES offer solutions to your original equipment problems, write Gast. Oil-less models from 10 to 20 inches vacuum — 3 to 10 lbs. pressure — 3.5 to 24 C.F.M.

Write for new Data Sheet on Oil-less Pumps, showing 3 types and rating tables.

Original Equipment Manufacturers for Over 25 Years

GAST ROTARY
AIR MOTORS · COMPRESSORS · VACUUM PUMPS
(TO THREE H.P.) (TO 30 LBS.) (TO 28 INCHES)
GAST MANUFACTURING CORP., 107 Niakley St., Benton Harbor, Mich.

(*Continued from Page* 280)

ing: "Doubts are traitors, and make us lose the good we oft might win, by fearing to attempt."

Especially in creative effort, we have every reason to sweep timidity aside and gird our efforts with audacity. The wilder we shoot, the more and bigger ideas we are likely to bag. As Carl Spier has said: "Let's not forget that almost all good ideas are crazy at birth. . . . Can you beat it?—they are going to put out a refrigerator which freezes ice with a flame! . . . What?—a plane with no propeller?"

Luckily, none of us will ever suffer from any lack of critics to tame down our ideas. Our friends may hold their tongues about our halitosis, but never about our brainstorms.

As Robley Feland has written, "High up in our resources for happiness, we can place the proved knowledge that we have the power to think ourselves out of trials and difficulties. Although it is impossible to lift ourselves over a fence by our bootstraps, it is possible—it can be easy—to lift ourselves over life's obstacles by the force of our applied imagination." Let's not underestimate our own creative powers—and let's put on our hunting caps!

From a paper of the same title presented at the SAE Central Illinois Section Meeting in 1951.

Hydraulic Drives for Aircraft

By K. I. Postel and R. A. Meade

Vickers Inc.
Detroit, Mich.

BASIC considerations in the design of a power transmitting device are its performance, weight, size, and cost. In the broad classification of hydraulic drives, requirements exist for three types which may be classified as: (1) constant ratio, (2) variable speed input and/or output, and (3) constant speed. In all of these drives the operating torque may vary independent of speed change, or may vary as the speed changes.

In general, any hydraulic drive will consist of a pump assembly and a motor assembly. Also, such items as a system overload relief valve, a reservoir, a supercharging device, filters, control pump and control mechanism are usually required. The performance capabilities of the drive, however, are primarily dependent on the performance characteristics of the motor and pump assemblies and speed control devices. The balance of the equipment consists for the most part of more standardized items that are adapted for use with the major components. Some applications require that the drive deliver only a portion of the total power; this type is usually called a split-torque drive.

Drive Classifications

Performance characteristics of the three general types of drives are:

1. Constant-ratio. Consists of fixed-displacement pump and fixed-displacement motor. By selection of displacement ratios, a drive can be obtained that will provide a fixed-speed ratio that may be equal to, less than, or greater than the input speed. These drives usually carry only a maximum torque rating, as this value is dependent on operating pressure, which in turn is governed by the design. Also, an upper speed limitation exists which is determined by the maximum rating of the pump and/or motor assembly. In cases where this value does not correspond with the installation requirements, suitable gear boxes are used.
2. Variable-speed. Also consists of pump and motor units. The two most widely used combinations are: (a) the variable pump and fixed-displacement motor combinations, and (b) the fixed - displacement pump and variable motor combination. The control or adjusting mechanism in this type of transmission usually receives its signal or impulse from associated equipment. The final stage of the control which is usually provided as an integral part of the transmission may consist of a proportional solenoid, a pilot control valve, and a hydraulic cylinder.
3. Constant speed. Essentially the same as the variable speed drive, except that it contains

a speed sensing element and regulating mechanism.

For all of these types of drives, the overall rating of any particular design is governed by the performance capabilities of the individual units.

Speed: The operating speed of a hydraulic unit depends upon its size; large units are normally rated at lower speeds than small ones. The limiting factors in determining the maximum practical speed are the velocity of flow of the fluid and the sliding or rolling velocity of bearing surfaces.

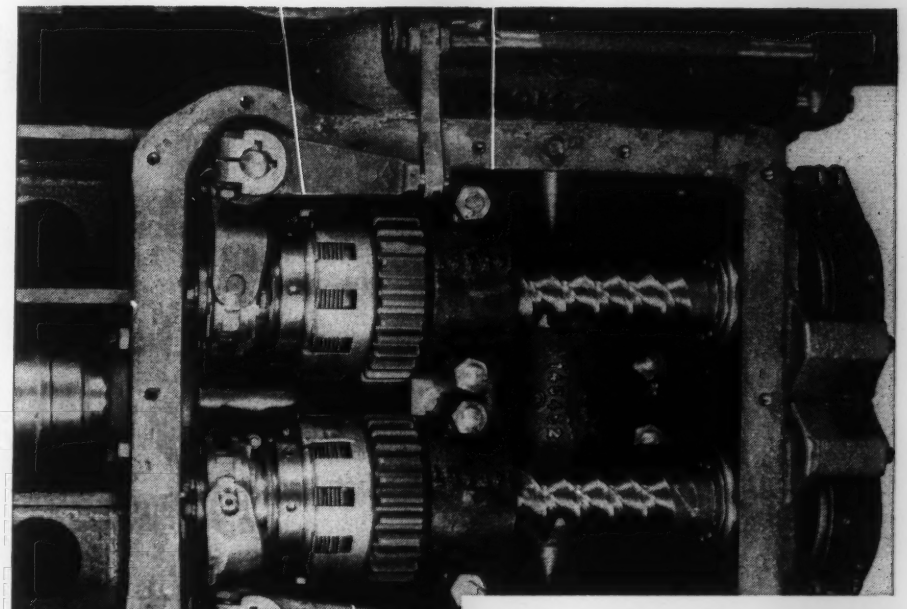
When the hydraulic circuit is a closed loop, as is generally desirable for drives, supercharging of the low pressure side of the circuit can be employed to allow higher oil velocities without danger of cavitation. Actually, experience has shown that approximately 40 fps is about the usable upper limit velocity of oil flow because of the rapidly increasing pressure drop encountered when operating in the higher speed ranges.

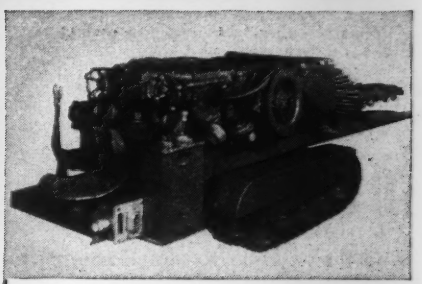
Leakage Affects Speed

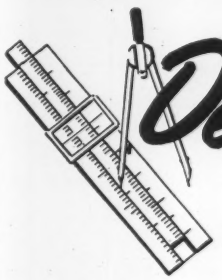
The range of speed over which any hydraulic motor may be operated depends upon many contributing factors, such as the nature of the source of fluid, the internal leakage of the motor and other items in the circuit, and the type of load. For continuous full load torque, about 8 rpm may be considered as a practical minimum speed relatively independent of unit size. In a special set-up where the hydraulic circuit is tight and the method of loading is carefully selected, large units may be operated with smooth output speed as low as 1 rpm.

A high ratio between maximum and minimum speed is very desirable for servo drive applications. The practical limit seems to be about 1250 to 1 for the smaller units and about 450 to 1 for the large size aircraft designs.

Torque: In selecting units for drives, and especially those for servo applications, it is extremely desirable that the stall-torque rating approach theoretical values as closely as possible. This characteristic is found in piston type designs, where the lowest value at any shaft position would not be







Design for *Better* digging

To help move minerals faster—to help use manpower and machines most efficiently—that's the job of machinery makers in the constant battle against high production costs.

One of the big mining costs is handling and loading. Machinery makers have produced many cost saving answers. A variety of muscle-saving, high production diggers, muckers, loaders, haulers, conveyors, help pour record tonnages from the mines. And as elsewhere throughout industry you usually find them "put to work" through Twin Disc Friction Clutches or Hydraulic Drives.

There's a Twin Disc drive for every application—a Twin Disc engineer available to help on your design and engineering problems.

For example: Goodman Manufacturing Company's Tractor Tread Trucks, Conway Mucking Shovels, and Types 360 and 460 Loaders, are equipped with Twin Disc Model MTS multiple disc clutches. Shown above is the Tractor Tread Truck, with the Twin Disc MTS Clutches that actuate it.

TWIN DISC
CLUTCHES AND HYDRAULIC DRIVES
REG. U.S. PAT. OFF.

TWIN DISC CLUTCH COMPANY, Racine, Wisconsin · HYDRAULIC DIVISION, Rockford, Illinois

BRANCHES: CLEVELAND · DALLAS · DETROIT · LOS ANGELES · NEWARK · NEW ORLEANS · SEATTLE · TULSA

"Trifles make perfection but perfection is not a trifle"—*Michael Angelo*

Not a Trifle

And it's no trifle to manufacture precision balls within ten millionth of an inch. The skill, perfection and preciseness applied to the manufacture of every Universal Ball is the reason why those who know fine balls best, will not accept less than Universal's precision perfection.

Universal Balls are 100% inspected and individually gauged. All high precision small balls made in this plant are slowly inspected under magnification.

If you want precision balls of unexcelled surface finish, sphericity, size accuracy and extremely fine tolerances, specify Universal Precision Balls.

They are the best balls for applications where high speeds, silent operation and minimum torsional resistance are determining factors.

UNIVERSAL BALL CO.

PRECISION BALLS OF CHROME AND STAINLESS STEEL, BRONZE AND SPECIAL METALS.

WILLOW GROVE, Montgomery County, Pa.
Telephone, Willow Grove 1200

less than 95 per cent of the theoretical output. As soon as smooth continuous rotation is achieved, the average running torque would be approximately 97 per cent of the theoretical value.

As the speed is increased from minimum smooth rotation to normal rated rpm, the torque efficiency will again go down to approximately 95 per cent due to the increased fluid and bearing friction losses at higher speeds.

Efficiency: The volumetric efficiency of piston type units is usualy exceptionally high. The losses that occur may be classified as leakage, compressibility of the fluid, cavitation, and deflection of the pump structure. The combination of all three of these losses may result in a total of about 1 per cent per 1000 psi, so that a pump operating at 3000 psi and rated speed can deliver 97 per cent of the theoretical displacement.

The leakage that occurs can be reduced by designing for longer sealing lengths, employing closer fits, and machining more accurate surfaces. Each of these factors, however, may represent a sacrifice in some other feature.

Slip Values Misleading

For variable-displacement pumps, the terms "volumetric efficiency" should be avoided, since for a given unit size the leakage will be somewhat proportional to pressure and almost entirely independent of either speed or volume setting. Care must be used also even with a known slip value because a particular design of unit may show a fairly linear volumetric loss curve through its normal design range and then at some pressure above that range, a point may be encountered where a small increase in pressure will result in a large increase in slip.

The compressibility of the fluid depends upon its composition and also on aeration. Practically, the compressibility factor is generally between ¼ and ½ of 1 per cent per 1000 psi, the fluids used in industrial application being closer to the ¼ and the lighter fluids such as are used in aircraft more nearly approaching ½.

Volumetric loss due to structural deflections can, of course, be reduced by simply making parts more rugged. However, present day designs seem to be leaning toward the rugged side already, and therefore not too much return could be expected from a program aimed at "beefing up" current models. At any rate, the effects to be gained by operating with adequate inlet pressure yield results of greater magnitude than remains to be gained by stiffening the construction, though to some extent a high supercharge may operate mainly as a means of picking up the mechanical backlash portion of structural losses.

Altitude Cuts Delivery

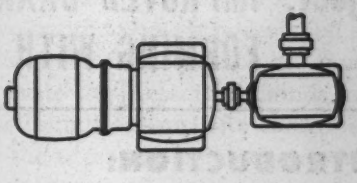
The decrease of delivery as absolute inlet pressure is decreased is apparent on many aircraft installations where open circuits are used at high altitudes. The difference in delivery of a hydraulic pump from normal atmospheric pressure down to ½ atmospheric pressure may be as much as 6 per cent. Sufficient supercharge to maintain high volumetric efficiency is easily obtained with very small power consumption by the use of a closed circuit and auxiliary replenishing equipment.

The torque efficiency of piston type units, both pumps and motors, easily reaches 95 per cent at rated pressures, and is substantially constant from stall to full speed, as has been noted before. It takes about 30 psi to start rotation of an unloaded hydraulic motor, and about 15 to 20 psi to maintain continuous smooth turning. Motors have been made which will idle on 5 psi, but the refinements and compromises were not consistent with the small gain in efficiency. On a unit with a rated speed of 3000 rpm the pressure required to idle it at that speed would be about 80 psi, the increase being mainly absorbed in velocity pressure drop through the ports. Because of these inherent losses, it is not possible to vary the displacement of a single hydraulic motor much more than about 4 to 1.

Overall mechanical efficiency of a single piston type unit will consistently reach 92 per cent at rated speed and pressure, so that two units combined into a drive can have an overall efficiency of 85 per

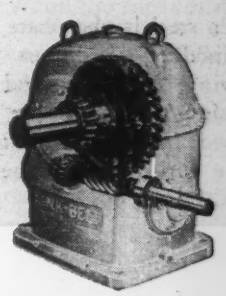
Which of these speed reduction jobs is yours?

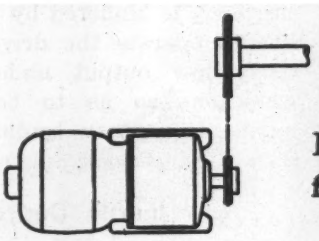
High-ratio reduction with right-angle takeoff?



Get a LINK-BELT Worm Gear Drive

Reduction ratios: 3.1:1 to 8000:1. Torque: 1400 to 123,000 in. lbs. Output shaft rpm: 0.22 to 564. Drawing shows motorized P.I.V. variable speed and worm gear drives direct-coupled.

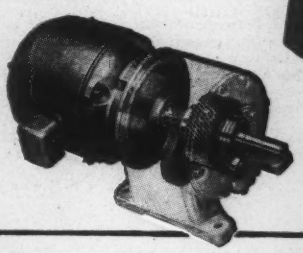




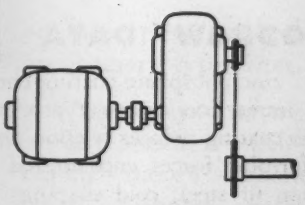
Restricted space for mounting?

Get a LINK-BELT Gearmotor

Reduction ratios: 6.2:1 to 292:1. Hp range: 1 to 30. Output shaft rpm: 6 to 280. Drawing shows gearmotor with roller chain drive.

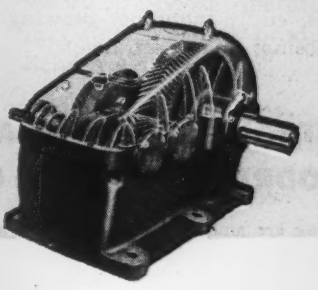


High hp with parallel shaft takeoff?



Get a LINK-BELT Herringbone Gear Drive

Reduction ratios: 2.84:1 to 318:1. Hp range: ½ to 1000. Output shaft rpm: 2 to 600. Drawing shows motor with herringbone gear and roller chain drives.



Yes, LINK-BELT builds all 3

NO LONGER need speed reduction be the limiting factor in a design or application problem. Because no *one* speed reducer solves every reduction problem, Link-Belt builds all three—Helical, Herringbone and Worm. Now it is only necessary to choose the right type of Link-Belt enclosed gear drive . . . and select the hp and reduction ratio that fit your requirements. You can get complete engineering information from the Link-Belt office near you.

12,000

LINK-BELT

ENCLOSED GEAR DRIVES

LINK-BELT COMPANY Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa), Sydney (Australia). Offices, Factory Branch Stores and Distributors in Principal Cities.

AMERICAN CHEMICAL PAINT COMPANY
AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet
Subject: IMPROVED DRAWING AND COLD FORMING WITH GRANODRAW

INTRODUCTION:

When steel is phosphate coated with "Granodraw" prior to working it, drawing, extrusion, and other cold forming operations are greatly improved. In fact, the protective phosphate coating makes the cold extrusion of steel possible.

Getting cold steel to flow depends on the unique properties of this coating. Its non-metallic phosphate crystals are physically and chemically adapted to acquire a strongly adsorbed lubricant. The combination of adherent phosphate coating and adsorbed lubricating film possesses a low coefficient of friction while maintaining its integrity under extremely high deforming pressures.

The drawing of wire and many other cold forming operations — including the cold extrusion of steel — are greatly facilitated by the application of a "Granodraw" phosphate coating and a suitable lubricant prior to working.

"GRANODRAW" DATA

"Granodraw" zinc phosphate coating chemical is applied to pickled surfaces in an immersion or spray process. When used with a suitable lubricant, the coating reduces friction under conditions of low, medium, or high deforming forces encountered in such typical operations as: cold extrusion of steel; cold shaping; deep drawing (tubs, cartridge cases, shells, etc.); stamping; drawing of wire and tubing; ironing; necking; nosing; and upsetting.

ADVANTAGES OF PHOSPHATE COATING WITH "GRANODRAW" PRIOR TO COLD FORMING STEEL

The following are among the advantages indicated for phosphate coating with "Granodraw" prior to cold forming steel:

Drawing of wire, bars, tubing, etc. — Improved lubrication; improved surface; less scratching; reduced pull; greater percent reduction per pass; reduced die wear; longer die life; lower die maintenance and cost; reduction in corrosion.

Drawing of stampings, shells, shell cases, etc. — Improved lubrication; reduced breakage; reduction in scrap; deeper draws; less scratching; elimination of some annealing; less wear on dies.

Cold Extrusion — Improved lubrication; increased strength of parts; improved surface; reduction in load on press; greater dimensional accuracy; more uniform wall thickness; longer extrusions; elimination of some annealing; less corrosion.

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "GRANODRAW" AND ON YOUR OWN METAL PROTECTION PROBLEMS.

CHEMICALS ACP PROCESSES

cent at rated output power. In the larger sizes, the efficiency of a single unit has been measured to be between 93 and 94 per cent repeatedly. The proportionate size of bearings and the surfaces exposed to viscous drag are favorable to the larger units. The curve of overall efficiency at rated speed with varying pressure is surprisingly flat. The maximum efficiencies stated are difficult to achieve in servo mechanisms because of the tendency to operate at speeds above normal, to use small hydraulic lines to keep the volume under pressure as small as practical, and because of the relatively large control energy required. Quite often the realization of high efficiency is hindered by the necessity to operate the drive at relatively low output under normal conditions so as to be able to handle emergency loading for intermittent periods.

Low Inertia Desirable

Acceleration: The ability to accelerate rapidly is a very important feature of an aircraft hydraulic drive. This is not so much because of any desire to reach a predetermined operating speed in the least possible time, but rather it has to do with the ability of the drive to recover rapidly from sudden application of load. In the class of hydraulic drives which operate strictly as servo units it is obvious that acceleration is of prime importance in permitting rapid response to the input signal. One of the most outstanding features of piston type pumps and motors is their low inertia.

Noise: The noise emanating from hydraulic systems, and especially from hydraulic pumps, has been an objectional feature in some installations. The chain of events seems to have been first, to develop a unit for performance and later to try to overcome the noise without impairing efficiency. The principal factors affecting the noise level output are the weight of the parts, the speed of rotation, and the operating pressure. Considerable progress is being made in the direction of reducing the inherent noise of the units. As an added bonus, bearing life has been increased because much of the shock

Operator confidence soars—and so does production—with the Schrader Press Control. For this control is definitely a two-hand device. It is designed so that the hands that feed the die must also operate the press. Both hands must be used simultaneously for each operation of the press and cannot stray into the danger zone when the ram comes down.

This *increased safety* of Schrader's Press Control lets operators build a worry-free rhythm that puts new speed in your presses in just a short time.

What's more, Schrader Controls end the fatigue common with mechanical foot pedal operation—a Schrader-

Reduce Danger Here

equipped press can be run as easily as an ordinary typewriter.

Wherever you have a power press—or any machine with a mechanical clutch—there's a chance to increase safety . . . boost operator confidence and thus increase production with a Schrader Control.

Let us help you decide what will best fit your needs. Write, describing the machines you plan to use—or fill out the coupon below.

Schrader
REG. U. S. PAT. OFF.

products
control the air

Air Cylinders • Operating Valves • Press & Shear Controls • Air Ejection Sets • Blow Guns • Air Line Couplers • Air Hose & Fittings • Hose Reels • Pressure Regulators & Oilers • Air Strainers • Hydraulic Gauges • Uniflare Tube Fittings

Mail This Coupon Today

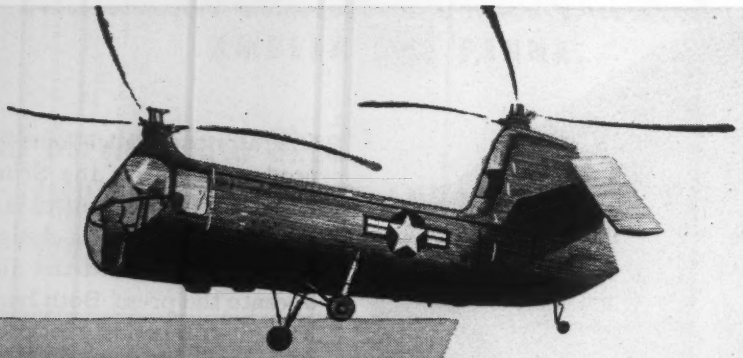
A. SCHRADER'S SON
Division of Scovill Manufacturing Company, Incorporated
476 Vanderbilt Avenue, Brooklyn 17, N. Y., Dept. V-1

I am interested in more information on.....

Name_____ Title_____

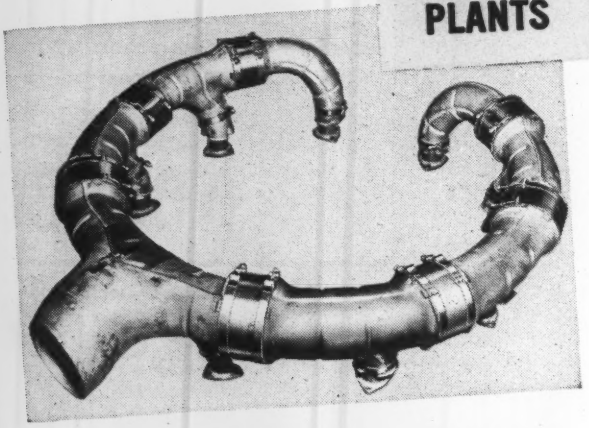
Company_____

Address_____



ENGINEERS NOTEBOOK

POWER PLANTS



Multiple Take-up Clamp Simplifies Shroud Connections

The collector ring of the Piasecki HUP-1 helicopter is shrouded to insulate the structure from heat produced by the buried engine. Marman multiple take-up clamps provide a simplified means of coupling the titanium shroud sections together. A very slight modification of a standard clamp design was employed to accommodate this specialized application. Clips were spot-welded to the edge of the clamp, enabling it to apply a coupling action in addition to the clamping action usually associated with this type of clamp. This clamp brings about significant savings in weight, cost and time of assembly and disassembly. The patented T-Bolt latch assures a vibration-proof positive seal at all times.

Save Time, Weight, Money with Marman

FOR INFORMATION AND LATEST CATALOG, WRITE DEPT. M-4

3-420
15

MARMAN PRODUCTS CO., Inc.
940 W. FLORENCE AVE.
INGLEWOOD, CALIFORNIA

which produced the noise has been eliminated.

Temperature: The operating temperature range through which this type of equipment will perform satisfactorily is very broad. At the lower end of the range the pour point of the fluid is usually the deciding factor. With the present aircraft fluid −65 F is the low, and it is interesting to note that it is practically impossible to distinguish any increase in the torque required to turn a piston type unit at −65 F as compared to room temperature. At the upper end of the range the ability of gaskets, "O" rings, and shaft seals is the main limiting factor. At present 180 F is the normal high with 200 F allowed intermittently.

Leakage Aids Servos

Most hydraulic units for aircraft application are special, and this is more than ever true with hydraulic servo units. Mathematical analysis indicates that an increase in leakage will improve the dynamic response of a transmission to a sinusoidal input signal. However, this improvement is obtained at the expense of efficiency, static accuracy, and transient response. The effect on the efficiency is not trivial when one considers that the amount of leakage needed to do any appreciable good is likely to amount to 20 to 50 per cent of the total volume, whereupon it is discovered that the next larger size pump is required, and that to drive this pump calls for a larger motor. Therefore, any tendency to arbitrarily increase leakage to improve response must be carefully analyzed in order to maintain the most desirable characteristics for the overall system.

As the speed of response required in a drive is raised higher and higher, more and more power is required in that portion of the mechanism which changes the stroke or otherwise controls the output of the variable components of the transmission. In general, about 15 per cent of the total maximum power being handled is allocated to the purpose of controlling the output. If the amount of power being fed into the controls were ever to approach or exceed 50 per cent of that being trans-

Fine machines begin with FINE BEARINGS

Despite the emergency you are probably doing some long-range planning . . . exploring the possibilities of the day when all-out production of civilian goods will again demand emphasis on advanced design.

In exploring the possibilities of your products' future, it will pay you to remember this basic truth: Fine machines begin with fine bearings . . . and "fine bearings" is simply another way of saying Ahlberg Bearings.

For more than four decades design engineers have found that Ahlberg Bearings offer outstanding opportunities for improving design, increasing stamina, reducing maintenance and cutting cost.

Of course, right now, early delivery promises on non-military requirements are next to impossible, but there's never a shortage of sound engineering service at Ahlberg. Please feel free to ask for it at any time. Ahlberg Bearing Company, 3025 W. 47th St., Chicago 32, Illinois.

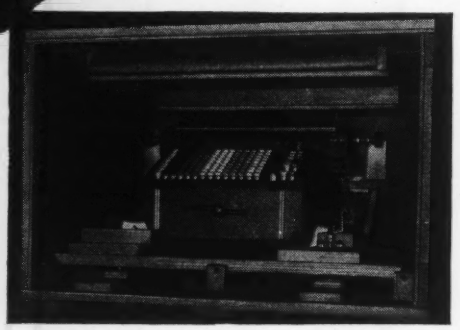
AHLBERG

BALL BEARINGS

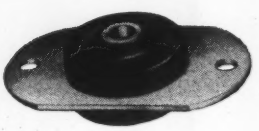
ENGINEERED AND BUILT FOR THE WORLD'S FINEST EQUIPMENT

AUTOMOTIVE . . . INDUSTRIAL . . . AIRCRAFT . . . MARINE . . . ARMAMENT

A Smooth, Safe Ride for SENSITIVE EQUIPMENT.



LORD SHIPPING MOUNTS, *of course!*



Say goodbye to the costly servicing of sensitive equipment at destination — For one user Lord Shipping Mounts cut service and inspection time on overseas shipments from as many as 30 hours to only 4 hours.

Lord Shipping Mounts in your cases protect sensitive mechanisms in transit by cushioning the shocks of rough handling. This protection prevents maladjustment, greatly reducing costly servicing at destination.

If you are paying sizable service and inspection charges on newly shipped machines, stop it now. Lord Engineers will help you. Lord Shipping Mounts provide shock protection far superior to any other packing method . . . and they can be used indefinitely. To cut your shipping costs call or write to—

BURBANK, CALIFORNIA
Joe B. Hartley
George E. Behlmer
233 South Third Street
ROckwell 9-2151
CHarleston 6-7481

CHICAGO 11, ILLINOIS
Robert T. Daily
Kenneth L. Hanson
Perry C. Goodspeed, Jr.
520 N. Michigan Ave.
MIchigan 2-6010

DALLAS, TEXAS
Bruce O. Todd,
1613 Tower Petroleum Building
PRospect 7996

DAYTON 2, OHIO
W. Webster Dalton
238 Lafayette Street
MIchigan 8871

DETROIT 2, MICHIGAN
Everett C. Vallin
7310 Woodward Ave.
TRinity 5-8239

NEW YORK 16, NEW YORK
Vincent Ellis
Jack M. Weaver
280 Madison Avenue
MUrray Hill 5-4477

PHILADELPHIA 7, PENNSYLVANIA
George P. Harrington
725 Widener Building
LOcust 4-0147

ERIE, PENNSYLVANIA
Paul E. Dailey
Harry C. Sapper
1635 West 12th Street
2-2296

LORD MANUFACTURING COMPANY • ERIE, PA.

LORD BONDED RUBBER

HEADQUARTERS FOR
VIBRATION CONTROL MOUNTINGS
. . . BONDED RUBBER PARTS

system would become questionable. It would then be likely that a decision would be made to throw away the drive and do the entire job with the controlling mechanism.

"Noise" Causes Problems

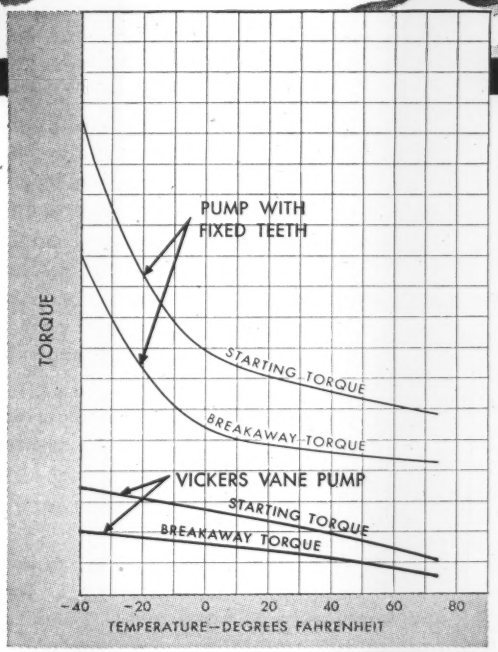
One of the more or less unforeseeable difficulties encountered in the development of high-response drives is the matter of extraneous noise. The term "noise" as employed here denotes vibrations and electrical hash picked up from other parts of the plane, and transmitted through the signal system resulting in a rash of dashing back and forth, absorbing unnecessary power, producing unwanted heat, and even promoting instability of the system. Many of the high-response drives in use employ electrical means for detecting, making computations upon, and amplifying the signal, which is then imposed upon some torque motor or proportional solenoid. The mechanical output of this electrical device may then go through one or more stages of hydraulic amplification before control of the actual drive is realized.

Weight: While the small units are handicapped by the greater proportion of hardware, wall thickness, bosses, etc., by virtue of the fact that they can be operated at much higher speed the return in power per pound is better than for the larger sizes.

Size: The concept of size is a relative matter. In comparing a fixed displacement pump with an electric motor of similar rating, the advantage would be with the hydraulic unit. On the other hand, the comparison of an infinitely variable hydraulic drive to a gear box of equal power rating would be unfavorable toward hydraulics. These, of course, are hardly fair comparisons, as the results obtained are different. Size also has to be considered as including the problems relative to shape, volume, and attitude of installation. This is especially true in the case of the larger capacity drives because it is necessary, in many cases, to compete for installation space with other required accessories. Unfortunately, in many cases, size

MUCH EASIER COLD-WEATHER STARTING

An Important Advantage



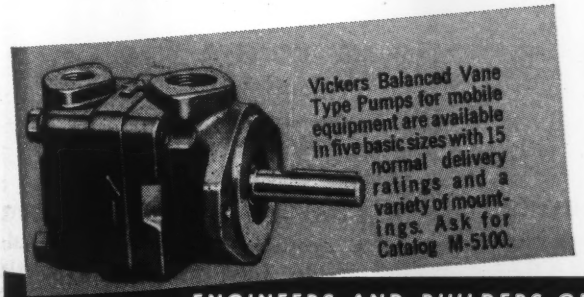
Curves based upon comparative tests of a Vickers Vane Type Pump and one with fixed teeth of equal capacity. Oil used complied with Army Spec. 2-79-B.

With VICKERS
BALANCED VANE TYPE PUMPS

Cold weather imposes a double handicap in starting. All engine parts tend to be stiffer, and the power of the starting battery is greatly diminished. In vehicles furnished with power hydraulic equipment, the starting load may be seriously increased when a pump with fixed teeth or lobes is directly connected to the engine.

Vickers Balanced Vane Type Pumps do not have this effect. At rest and at normal starting speeds, the sliding vanes are retracted...only after the engine fires do the vanes expand and pumping begins. The result is that Vickers Vane Type Pumps make cold weather starts much easier.

For further information, get in touch with the nearest Vickers office listed below.



Vickers Balanced Vane Type Pumps for mobile equipment are available in five basic sizes with 15 normal delivery ratings and a variety of mountings. Ask for Catalog M-5100.

VICKERS Incorporated

DIVISION OF THE SPERRY CORPORATION

1430 OAKMAN BLVD. • DETROIT 32, MICH.

Application Engineering Offices: **ATLANTA • CHICAGO (Metropolitan) • CINCINNATI • CLEVELAND • DETROIT • HOUSTON • LOS ANGELES (Metropolitan) • NEW YORK (Metropolitan) • PHILADELPHIA • PITTSBURGH • ROCHESTER • ROCKFORD • ST. LOUIS SEATTLE • TULSA • WASHINGTON • WORCESTER**

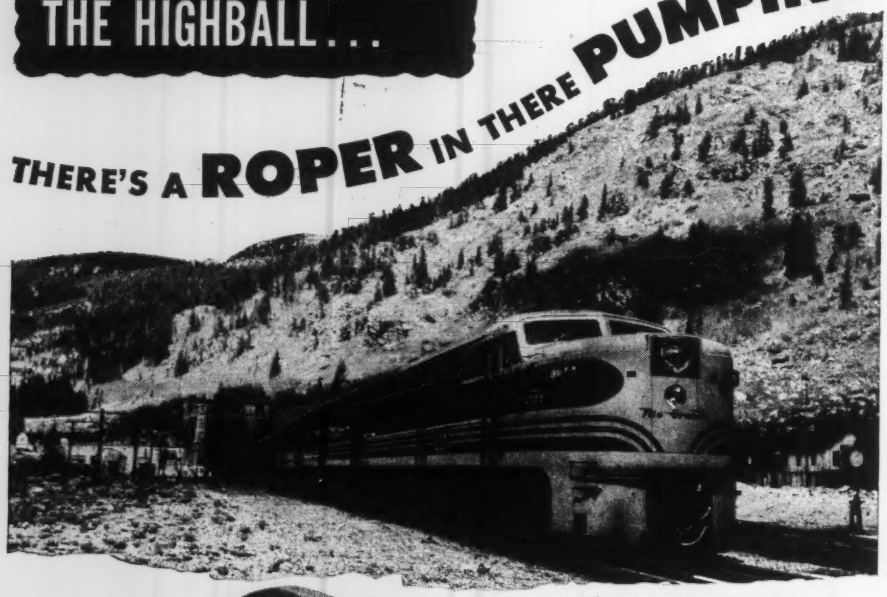
4768

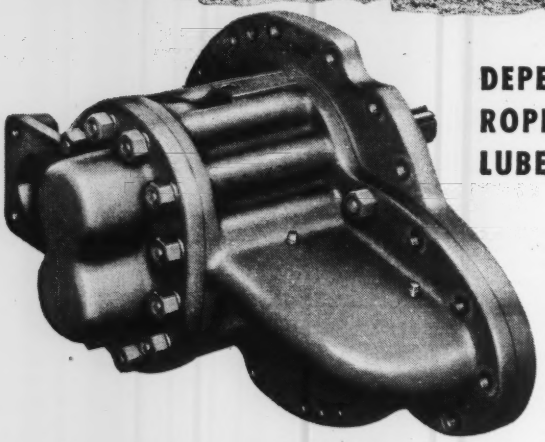
Ask for New Catalog M-5100

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

WHEN THEY GIVE 'ER THE HIGHBALL...

THERE'S A ROPER IN THERE PUMPING





THIS LOCOMOTIVE DEPENDS ON A SPECIAL ROPER PUMP FOR MAIN LUBE OIL SERVICE

"A heavy duty pump for main lube oil service . . . compactness . . . rugged from shaft to ports" — that's generally what the specifications called for. So, we tackled the job and developed this special "tough service" pump for diesel engines such as the ones used in the Rio Grande "Prospector".

SPECIAL AND STANDARD MODELS FOR YOUR APPLICATION

This custom built lube oil pump for diesel applications operating at 1160 r.p.m. delivers 267 g.p.m. at 90 p.s.i. Although of special design, it employs the basic Roper principle — only 2 moving parts. In addition to special applications, there are Roper standard pumps of varied size and design which may be adapted to your needs. These include: SERIES 3600: pressures to 60 p.s.i. — 40 to 300 g.p.m.; SERIES F: 300 p.s.i. — 1 to 300 g.p.m.; SERIES H: 1000 p.s.i. — 5 to 75 g.p.m., and SERIES K: 150 p.s.i. — 3/4 to 50 g.p.m. For more detailed specifications on these dependable pumps, write for your catalog today.

ROPER Rotary Pumps

SEE OUR CATALOG IN SWEET'S

GEO. D. ROPER CORP.
244 Blackhawk Park Ave.
ROCKFORD, ILLINOIS

cannot be used as the final item of comparison in view of the fact that power plants available today and in the near future impose design limitations as far as torque output and clearance envelope are concerned. While hydraulic drives can be provided with the pump mounting directly on a take-off pad and the output end delivering the desired speed directly to the driven accessory, many installations, because of the aforementioned space, torque or speed limitations, make it necessary to use step-up or step-down gear boxes at the input and output shafts.

Life: In choosing equipment for a specific application, the duty cycle must be very thoroughly studied and evaluated. As far as service life is concerned, in many cases the duration or extent of operation in terms of hours may not be as critical as the severity of loading, shocks, speed variation or intermittent overloads. Other than outright misapplication of the equipment, the one factor having the most influence on service life is that of contamination of the hydraulic system with foreign material. The designer in his calculations and study must necessarily assume that proper precautions will be taken at the time of installation to assure that the system be kept clean. He should also incorporate filters and other protective devices in his system design. However, if the tubing is not properly cleaned, and fittings and flares are not deburred, or if the units are stored without the use of proper closures, considerable trouble and difficulty will result.

From a paper of the same title presented at the SAE Annual Meeting in 1952.

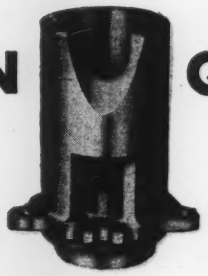
Improving Steels for Low-Temperature Service

By G. W. Geil, N. L. Carwile, and T. G. Digges

Thermal Metallurgy Laboratory
National Bureau of Standards
Washington, D. C.

MOST ferrous metals, including ordinary carbon and low-alloy steels, tend to become brittle below certain low transition tem-

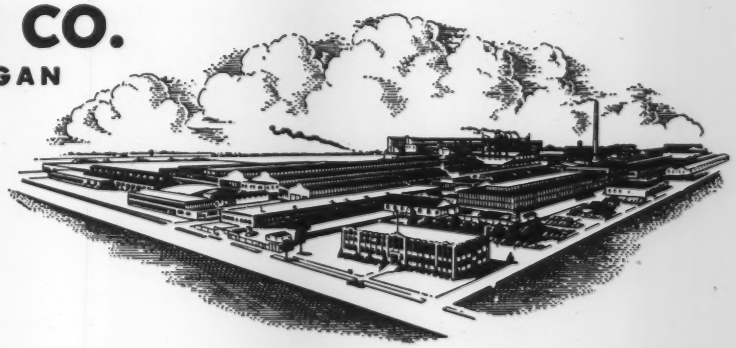
MUELLER BRASS CO. CAN GIVE YOU FAST DELIVERY OF QUALITY CASTINGS IN PRODUCTION QUANTITIES ...AT THE RIGHT PRICE



The Mueller Brass Co. can produce sand castings to your specifications from practically all copper and brass alloys including red and yellow brass . . . phosphor, manganese and aluminum bronze . . . and nickel silver. Modern production equipment plus engineering knowledge and years of foundry experience make possible fast delivery of high grade, low-cost castings. Mueller Brass Co. has complete foundry facilities to handle all casting production problems. There is a well-equipped tool room and pattern shop . . . a battery of electric melting furnaces . . . high capacity core room . . . bench and floor molding equipment to handle a wide range of casting sizes. Then too, Mueller Brass Co. has the metal working facilities to give you high strength, close-grained, uniform castings machined, polished or plated as you prefer. Mueller Brass Co. can give you the sand castings you need and the service you want . . . write today.

80

MUELLER BRASS CO.
PORT HURON 15, MICHIGAN



Design

to

PROTECT EQUIPMENT

from

THREAD FAILURES

Heli-Coil* screw thread inserts provide positive protection against wear, stripping, and corrosion in all threaded fastenings. Precision formed of stainless steel or phosphor bronze wire, these inserts permit impressive savings in weight and space . . . greatly increase the strength of threads in aluminum, magnesium, die metal, plastics, and light castings of iron or steel. Galling, seizure and corrosion are totally eliminated . . . repeated disassembly and reassembly cause no wear of tapped threads.

Adjusting itself automatically to the mating threads, the ***Heli-Coil*** insert compensates for lead error . . . distributes the clamping load over *all* the threads. You can use shorter thread engagement for a given screw tension, and smaller boss sections too. In terms of the overall assembly, this means a more compact, lightweight, functional design . . . assuring you of compounded savings all along the line.

Heli-Coil inserts meet all industrial and military specifications for National Coarse, National Fine, and Unified Threads . . . and for spark plug and pipe threads. Available for Classes 3, 3B, 2 and 2B fits in all popular sizes from 4-40 to 1½-6.

*Reg. U.S. Pat. Off.

FOR THE FULL STORY, SEND US THE COUPON BELOW

HELI-COIL CORPORATION

124 SHELTER ROCK LANE, DANBURY, CONN.

Please send me ☐ Bulletin 650 on Design Data
☐ Bulletin 349 on Salvage and Service

NAME_____

FIRM_____

STREET_____

CITY_____ ZONE____ STATE_____

1501

peratures. Many steels that are satisfactory at ordinary temperatures may thus present serious fracture hazards under very cold operating conditions. Low-temperature characteristics of metals may become particularly important in aircraft operating at high altitudes or in cold climates, in military vehicles and equipment for arctic use, and in refrigerating equipment.

This low-temperature increase in brittleness, or loss of toughness, is generally accompanied by a decrease in ductility, by a decrease in energy absorbed in fracturing, and by a change in appearance of the fracture surface; this surface is fibrous in appearance in higher-temperature fractures but becomes granular in fractures occurring at lower temperatures. Transition temperatures depend on many factors, including chemical composition, the manufacturing process, subsequent thermal and mechanical treatment, and method of applying stress. Even if it is not introduced intentionally, a certain amount of nitrogen normally finds its way into steel in the course of manufacture. Knowledge of the effect of nitrogen on low-temperature brittleness, as well as on other steel characteristics, therefore, becomes important.

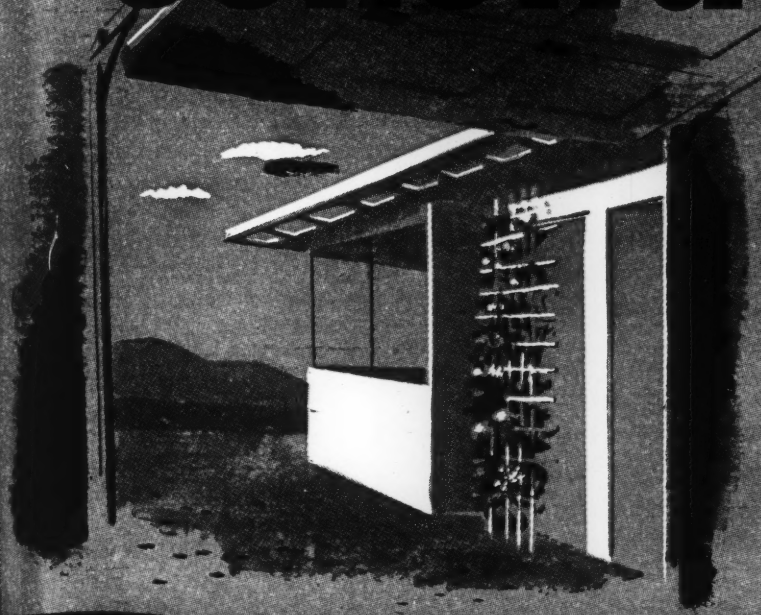
Aluminum Nitride Best

Results of fracturing V-notch specimens in Charpy impact tests indicate that increased nitrogen, if present as aluminum nitride, improves the low-temperature notch toughness—lowers the temperature at which brittleness appears — in certain carbon steels. But nitrogen in the form of nitrides of iron or manganese is apparently detrimental from the same standpoint.

The samples studied were of 0.3-per cent carbon steels containing 0.9 to 1.6 per cent manganese, 0.2 to 0.3 per cent silicon, and variable nitrogen. Included was one aluminum-treated series. Notched specimens were fractured in impact at temperatures ranging from −196 to +100 C (−320 to +212 F). The aluminum-treated steels tested showed much better low-temperature notch-toughness than the steels not so treated; transition temperatures, at which behavior

Van Huffel
cold-formed metal shapes
and tubing are basic
in better

building construction

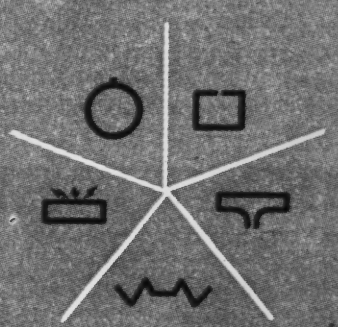


Whether hidden from sight doing a functional job or exposed to view just looking pretty, you'll find Van Huffel serving modern building construction needs in practically every nook and corner.

Architects, designers and engineers, knowing the structural advantages and versatility of Van Huffel metal shapes and tubing applications, are continually thinking up new uses. Wherever strength without excessive weight . . . beauty without complicated assembly are necessary characteristics, Van Huffel is basic in better building construction.

VAN HUFFEL

TUBE CORPORATION • WARREN, OHIO



ILDED, LOCK SEAM, OPEN SEAM, BUTTED TUBING, SHAPES AND MOULDINGS

can old age "cripple" your important drawings?

Not if you put them on Arkwright Tracing Cloth. Arkwright Cloth is the best insurance you can get that your drawings will never become brittle or opaque with age — never get paper-frayed around the edges to spoil your work.

Arkwright's extra quality shows right from the start. You can re-ink clean, razor-sharp lines on Arkwright Tracing Cloth over the heaviest erasures without feathering or "blobbing". And you can get clean, clear blueprints — if you need to — for years and years to come.

All good reasons for you to remember: if a drawing is worth saving, put it on Arkwright Tracing Cloth. Write for samples now to Arkwright Finishing Co., Industrial Trust Bldg., Providence, R. I.

ARKWRIGHT
Tracing Cloths
AMERICA'S STANDARD FOR OVER 30 YEARS

changed from ductile to brittle, were approximately 30 to 50 C (54 to 90 F) lower for the aluminum-treated specimens. Transition temperatures ranged from −45 or −50 C (−50 to −60 F) for the non-aluminum-treated steels to −80 or −95 C (−110 to −140 F) for the aluminum-treated steels. In the latter the nitrogen was present as aluminum nitride, and transition temperatures decreased with increasing aluminum nitride content.

Reported findings by various past investigators of the effect of nitrogen content on low-temperature properties of steels have been inconsistent. Some investigators have reported decreased toughness and higher transition temperatures with increased nitrogen, while others have reported no appreciable effect. Other researchers have suggested that nitrogen may be beneficial if present in the form of aluminum nitride. This new study, indicating that nitrogen is beneficial to low-temperature notch toughness if present as aluminum nitride, but detrimental if in the form of other nitrides, tends to explain and reconcile the inconsistent earlier reports.

From a report entitled, "Influence of Nitrogen on the Notch Toughness at Low Temperatures of Heat-Treated 0.3 per cent Carbon Steel," appearing in the March, 1952 issue of The Journal of Research (National Bureau of Standards.)

Minimizing Friction and Wear

By F. T. Barwell

IN THE ideal bearing, hydrodynamic forces arising from the viscous nature of the applied lubricant are made to separate the surfaces with virtual elimination of wear and reduction of the tangential frictional force to a value which might be as low as one-thousandth of that occurring in the absence of lubrication. Such hydrodynamic forces are, however, generated only when circumstances are favorable and there are many instances in which their achievement is not possible, such as at the moment of starting a mechanism from rest. In such circumstances it is neces-

HYDRAULIC VALVES—

138 MODELS FOR EVERY NEED!

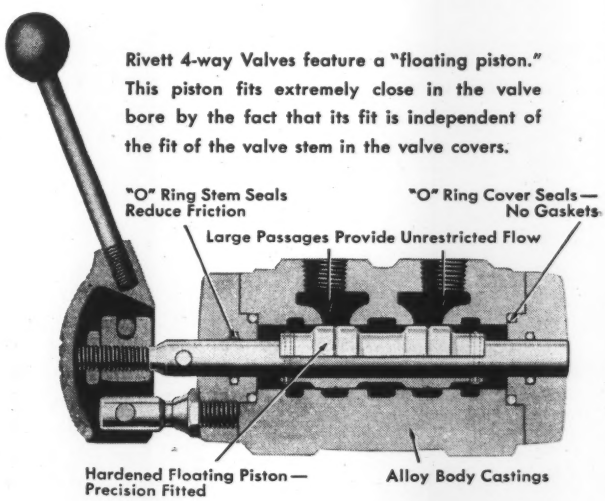
offered in 1500 P.S.I.—3000 P.S.I. for most models

Five piston designs to meet the requirements of any circuit

Six types of operation —hand, foot, cam, solenoid, oil pressure, air pressure

Four types of action —standard, spring return, spring centered, ball detent

Seven sizes available —¼", ⅜", ½", ¾", 1", 1¼", 1½"



Rivett 4-way Valves feature a "floating piston." This piston fits extremely close in the valve bore by the fact that its fit is independent of the fit of the valve stem in the valve covers.

You can plan a more efficient hydraulic circuit by choosing from the wide selection of Rivett valves. Every type of control is available, both direct and remote, including sequence, shut-off, check, relief, unloading, flow control and pilot. Not only does this Rivett variety assure you of a better operating system, but it also offers far greater latitude in design.

With Rivett you get the help of experienced distributors, who will assist in laying out the circuit best suited to your operating requirements.

RIVETT LATHE & GRINDER, Inc.
DEPT. MD-4 BRIGHTON 35, BOSTON, MASSACHUSETTS

RIVETT furnishes a complete power package

VALVES • CYLINDERS • POWER UNITS
Air and Hydraulic
All sizes and types

sary to rely on specific properties of a lubricant to reduce friction and prevent seizure, and this is described as boundary lubrication.

The effect of surface profile is of very great significance in frictional and wear problems. One great difficulty in studying the subject is that it is virtually impossible to change the roughness of the surface without simultaneously changing other factors such as hardness. However, there is evidence to show that in boundary lubrication it is possible to have too smooth a surface, just as a very rough surface is disadvantageous.

Possibly of greater importance than surface profile, is the chemical composition of the surface. It is now well known that most metals are covered with a naturally occurring oxide film. Where this film is stable it is usually not more than a millionth of an inch in thickness and serves to protect the remaining material from further oxidation. Where the oxide is permeable, no protection is afforded and corrosion is continuous as in the case of the familiar red rust of iron and steel.

Coatings Aid Lubrication

In the absence of film, metals in contact would weld, but the natural oxide aided by lubrication is able to prevent this. The nature of the oxide is important because, even when lubricated, the nature of the oxide affects the magnitude of friction recorded. There is thus a possibility of technological advance to be made by deliberately arranging for rubbing surfaces to be suitably coated.

One such process which has become increasingly well-known involves the conversion of the surface layer of the material to a phosphate. The process is very simple, the components are simply immersed in aqueous solution of proprietary reagents, which are kept at boiling point, for a period of 5 to 15 minutes. The surface is considerably roughened but loosely adhering particles can be removed by vigorous application of a wire brush. The treatment enables wear to be reduced considerably and is particularly effective in preventing local seizure and scuffing. The lub-

GO "AMERICAN" FOR CIRCULAR WELDED PRODUCTS

when product designers need help on products they specify and buy, American Welding offers 34 years' experience, complete designing, engineering and metallurgical service, where fusion or resistance welding of either ferrous or non-ferrous metals is required.

drop a line to our product development division

THE AMERICAN WELDING & MANUFACTURING CO. · WARREN, OHIO

Send for your copy of our 20 page illustrated catalog

LET US SEND YOU MORE FACTS OR BETTER YET SEND US YOUR SPECIFICATIONS FOR PROMPT QUOTATIONS

New Flexible Sealing...

T-J AIR CYLINDER

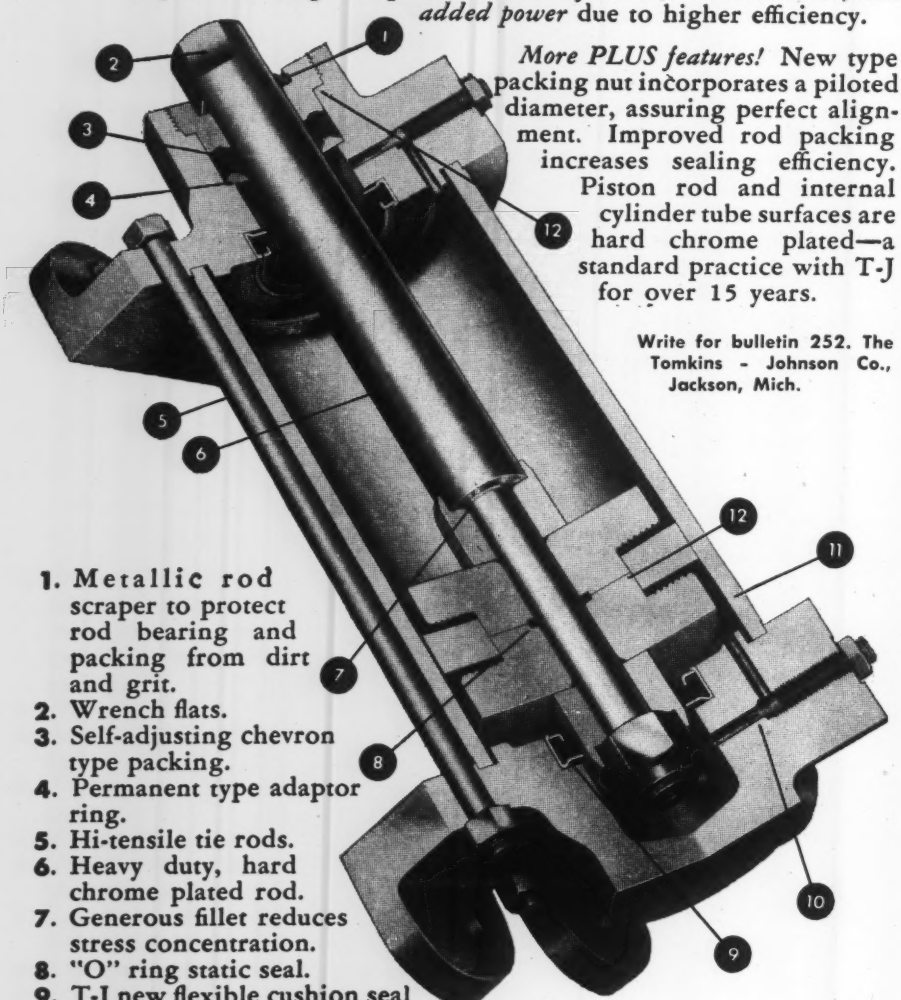
Designed with revolutionary application of

Super-Cushion

It's *sealed with pressure*—a revolutionary T-J application of flexible sealing that insures positive cushion action combined with automatic valving action for fast return stroke . . . eliminates binding and sticking . . . operates with *low friction, minimum wear,* and *added power* due to higher efficiency.

More PLUS features! New type packing nut incorporates a piloted diameter, assuring perfect alignment. Improved rod packing increases sealing efficiency. Piston rod and internal cylinder tube surfaces are hard chrome plated—a standard practice with T-J for over 15 years.

Write for bulletin 252. The Tomkins - Johnson Co., Jackson, Mich.



1. Metallic rod scraper to protect rod bearing and packing from dirt and grit.
2. Wrench flats.
3. Self-adjusting chevron type packing.
4. Permanent type adaptor ring.
5. Hi-tensile tie rods.
6. Heavy duty, hard chrome plated rod.
7. Generous fillet reduces stress concentration.
8. "O" ring static seal.
9. T-J new flexible cushion seal insures positive cushion with automatic valve action for fast return stroke. (Patent applied for)
10. Fine cushion adjustment.
11. Heavy wall precision honed hard chrome plate.
12. Controlled packing compression with metal to metal contact.

36 YEARS' EXPERIENCE T-J

TOMKINS-JOHNSON

RIVITORS · AIR AND HYDRAULIC CYLINDERS · CUTTERS · CLINCHORS

ricant is still necessary but becomes very much more effective, partly due to the antiwelding action of the phosphate layer which prevents or localizes seizure, and partly to its porous nature which provides numerous reservoirs for lubricant.

Forms of Wear

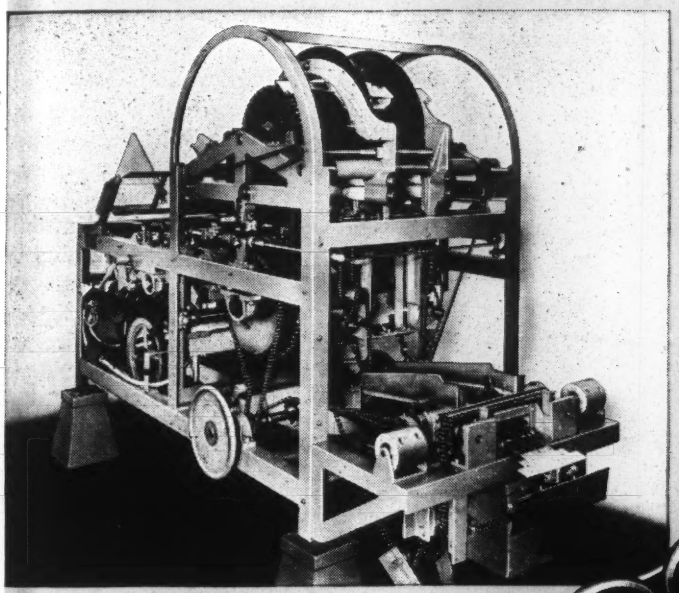
Wear, which may be defined as the unintentional removal of material from a surface, may take a variety of forms. The simplest concept is that, when the oxide films and the lubricant normally separating two surfaces are removed, the exposed areas bond together and, with continual application of tangential force, one or the other of the parts will shear.

When one of the materials is very much harder than another, or where abrasive particles are present between the surfaces, a form of abrasive wear may occur in which the particles actually cut away material from one or other of them. It is probable that this is one of the most common forms of wear met within engineering practice. Further, another continuous form of wear may be envisaged whereby the oxide film of one of the surfaces is continually removed and is replaced by a further film due to the action of atmospheric oxygen. This is closely analogous to corrosive wear which occurs in the presence of substances capable of vigorous chemical attack on the surfaces. This form of wear is one of the most urgent problems in internal combustion engine practice due to the increasing use of fuels with a high sulphur content. Wear may sometimes consist of a pastic deformation or flowing of the surface. The wear which occurs in practice is usually a combination of one or more of the elementary forms. For example, the debris arising from welding wear may easily give rise to abrasive wear.

Scuffing is a particularly difficult form of wear and should be distinguished from seizure. It usually occurs where high loads are met with in association with high speeds. In this circumstance, hydrodynamic effects arising from high speed afford protection until loading conditions cause local

Packaging Machinery Requires Accurate Timing Relationship . . .

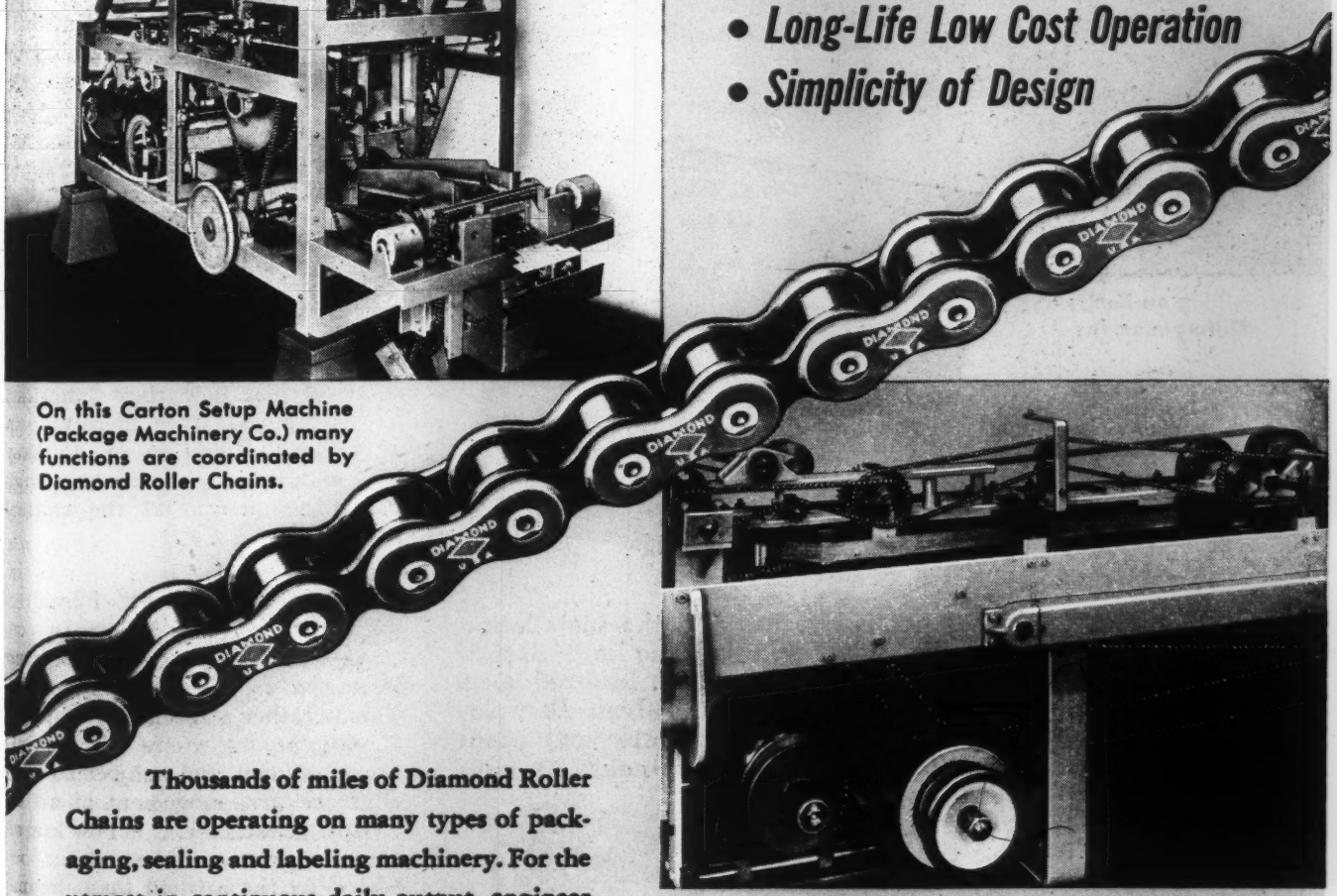
DIAMOND ROLLER CHAINS



On this Carton Setup Machine (Package Machinery Co.) many functions are coordinated by Diamond Roller Chains.

Provide:

- *100% Speed Ratio*
- *Maximum Power Transfer*
- *Long-Life Low Cost Operation*
- *Simplicity of Design*



On the Carton Closer, long lengths of Diamond Chains are employed.

Thousands of miles of Diamond Roller Chains are operating on many types of packaging, sealing and labeling machinery. For the utmost in continuous daily output, engineer designers recognize the uniformity, accuracy and dependability of Diamond Roller Chain where limits are expressed in thousandths of an inch. Quality control *maintained* at extremely close total length tolerances is one reason why Diamond Roller Chains are preferred.

For your materials handling equipment you'll find it pays to rely on Diamond, the chain with the Diamond stamp on the chain side-plate.

DIAMOND CHAIN COMPANY, Inc.
Dept. 435, 402 Kentucky Avenue, Indianapolis 7, Indiana
Offices and Distributors in All Principal Cities

DIAMOND **ROLLER CHAINS**

LET Valvair Substitute Air for Muscle!

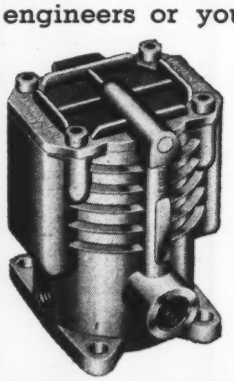
Slot-milling on Horizontal Milling Machine

Move lever of Valvair (D) to start cycle. Air cylinder (A) advances table to work. After cut, limit switch (F) actuates pilot valve (E), which returns valve (D) and cylinder (A) to starting position. Cam-operated Valvair (G) indexes part for next cut.

All air control valves and the installation are by Valvair. Valvair's basic body design fits nine control assemblies. Internal parts are also interchangeable. Valvair *Diversatility* puts real flexibility into your plant operation. Let Valvair engineers or your local Valvair representative help solve your problems involving pneumatic circuits.

* * *

Valvair's new solenoid pilot valve is used in the above installation. Available in 2-way and 3-way models, normally open or normally closed. Valve ordinarily operates over 20,000,000 cycles with no maintenance.



"Cut it out!"

☐ MORE INFORMATION ON VALVAIR LINE
☐ BULLETIN "D-4" ON NEW SOLENOID PILOT VALVE

Name, title_____
Company_____
Address_____

VALVAIR CORPORATION • 953 Beardsley Avenue, Akron 11, Ohio

Valvair DIVERSATILITY

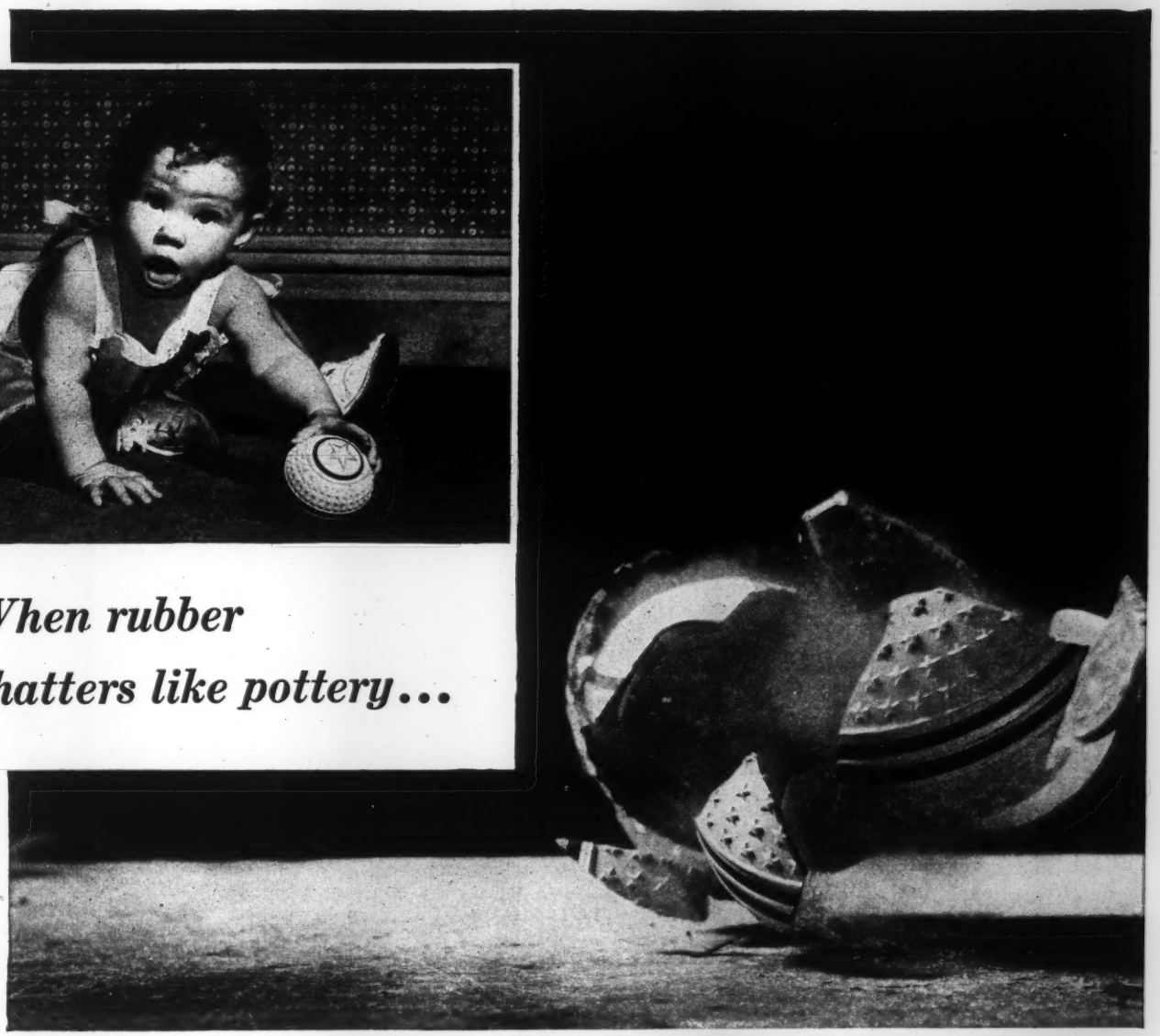
breakdown. When this occurs, the extreme conditions of speed and load afford potentialities for a rapid supply of energy to the critical surface resulting in welding, melting and the characteristic severe localized failure of the surface. Sometimes if speed is increased beyond the point causing scuffing, rapid wear of the surface of a less localized nature occurs, the removed metal being carried away as debris in the oil.

If scuffing is ascribed to inadvertent metallic contact at speed, means tending to limit the possibility of such contact would be expected to have a beneficial effect. For example, phosphating the surface does provide protection at the instant of breakdown of the lubricant and phosphated gears may be made to work more intensively than if they were untreated. Another palliative, which is very extensively used, is to incorporate chemically active agents in a lubricant so that protective films are formed at the points of weakness. It is certain that these additives act by attack on the surface; they may even increase the rate of wear. It is not, however, quite so well understood just how they function; for example, do they merely form a barrier to welding or do they melt and, in fact, constitute a high viscosity lubricant at the critical areas?

Oscillation "Frets" Film

Another distressing form of wear is known as "fretting corrosion." This is rather a special type in that it only occurs where components are in contact and subject to very slight relative movement of an oscillatory character. It is now known that the degree of corrosion is affected by the applied load, by the nature of surrounding atmosphere, and so on. A tentative theory accounting for the phenomenon is that the oscillatory motion breaks down any natural protective film carried by the surface, so that metal adheres and is broken away at each oscillation. Presence of lubricant may sometimes prevent the oxidation of these particles so that a scratching of the surface results. However, when free access of air and moisture vapor is allowed, the debris may be converted into an

When rubber shatters like pottery...



Natural rubber ball, chilled to minus 320.4° F., shattering on impact. Electronic flash tripped by microphone 1.035 milli-seconds after contact. Photos by Ralph Bartholomew, Jr.

Natural rubber *will* shatter, up in sub-stratosphere planes, at minus 50°F. Don't shiver; that's *warm* compared to temperatures some chemical equipment must take in stride.

Put yourself in the shoes of the man who designs an oxygen vaporizer. It must test 4200 pounds per square inch at minus 300°F.!

Or a helium liquefier that operates within 4 degrees of *Absolute Zero,* (which is exactly 459.6° below zero Fahrenheit).

Now that's cold. At temperatures like that, an orange spalls off in little chips, like granite. Steel brittles like a bit of glass.

In such a fantastic Jules Verneland, you discover that one *metal* and its alloys keep their toughness—ductility—clear down to 455° below zero F. Even the *"impact properties of weldments are essentially insensitive to temperatures as low as minus 320.4°F."*

So let's assume your problem is on the cool side, starting at 100° below zero and dropping off from that. You find the answer—as did the designers of the oxygen vaporizer and the helium liquefier mentioned above—in Nickel or a nickel alloy. (These two jobs were solved by Monel, an Inco Nickel Alloy.)

Let's Talk about Your Problem

Is it complicated too by sub-zero cold—or high heat, or corrosion, or some other difficulty?

Now is the time for us to get together with you or your engineers while our staff of metal specialists can carry out whatever research is needed to solve it. You can mail the outline of your problem direct to them for study by addressing it to The International Nickel Company, Inco Nickel Alloys Dept., 67 Wall Street, New York 5, N. Y.

Then the answer can be ready at your hand when these critical times are over, and Inco Nickel Alloys are available in any quantity for any use again.

THE INTERNATIONAL NICKEL COMPANY, INC.

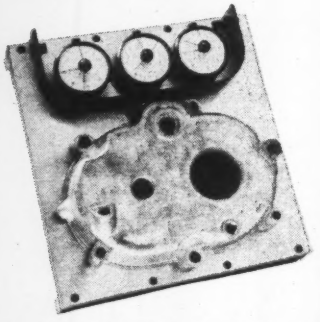
INCO TRADE MARK **Nickel Alloys**

Monel® • "R"® Monel • "K"® Monel • "KR"® Monel • "S"® Monel
Nickel • Low Carbon Nickel • Duranickel®
Inconel® • Inconel "X"® • Incoloy® • Nimonics

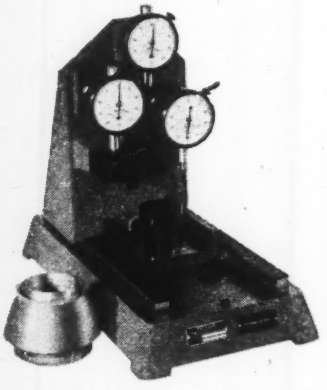
Dial Indicators for every gaging requirement—over 80 different models, ranges, sizes, graduations, styles.

Dimensional gages are specialized tools: their design and construction requires the knowledge and experience of specialists. Tell us your gaging problem. Perhaps one of the 25,000 gage designs in our files will answer your needs or can be adapted to meet your requirements. Not only does our vast fund of gaging information save development time but it probably can provide you with the right gage at less cost than creating a wholly new gage.

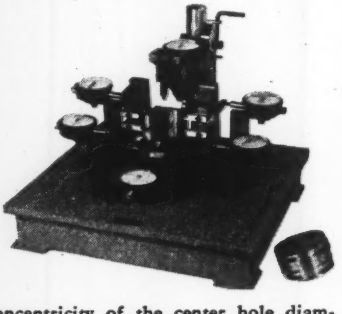
Our engineers are accustomed to working with product designers and will gladly cooperate with you on your dimensional gaging requirements. For the right answer, quickly and confidentially, bring your special gaging problem to Federal and take advantage of our long experience in designing and building dimensional gages. Send full details and blueprints to Federal Products Corporation, 1304 Eddy Street, Providence 1, Rhode Island.



Simultaneously checks the depth of three bosses on flange face of gear housing plate.



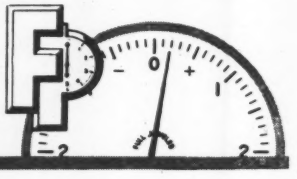
Checks height of two shoulders and depth of one groove of fuse body.



Concentricity of the center hole diameter, the inside diameter, three groove depths, an outside diameter — with the body diameter.

FEDERAL

Largest manufacturer devoted exclusively to designing and manufacturing all types of DIMENSIONAL INDICATING GAGES



abrasive oxide, which causes the severe damage met with in practice, the escaping oxide being often referred to by engineers as "cocoa" because of its brownish red color and small particle size. The phenomenon can therefore be regarded primarily as arising from metallic contact but the entry of oxygen provides a secondary phase which, from the engineering point of view, is very much more disastrous. This is borne out by certain experiments; for example, gold which does not oxidize, suffers damage of a scratching nature but steel in normal atmosphere produces copious supplies of damaging oxide.

Here again the artificial increase in the natural protection of the surface by the phosphating leads to very considerable benefit and the presence of oil tends to act as a barrier to oxygen, thereby minimizing the rate of attack. In practice, therefore, it is wise to adopt both methods, that is, phosphating to prevent metallic contact and supplying copious supplies of lubricant to remove debris and to minimize the supply of oxygen to any naked metal which may be exposed by penetration of the thick phosphate layer.

New Techniques Available

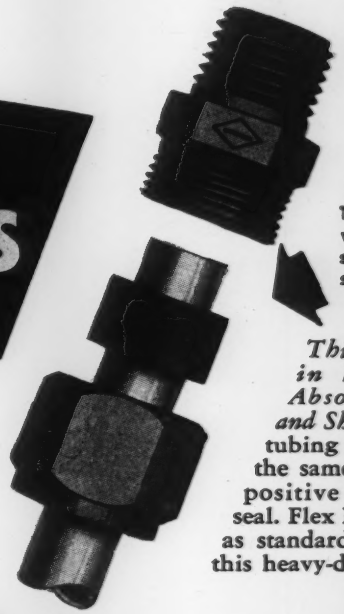
Our knowledge of frictional effects is by no means static. Powerful tools for research such as radioactive-tracer techniques are becoming available, with the result that is is possible to look deeper and deeper into the complicated phenomena of friction. Provided that such work can be carried out against a background of engineering practice so that the results may be applied rapidly in the form of improved designs or the use of new materials, the effort should be justified. It is probable that the outcome will not be the development of new lubricants or materials but a better understanding of the mode of operation of those already available so that their selection may be based on sounder premises, and bearing design amended advantageously.

From a paper entitled, "Some Aspects of Research on Friction and Wear," presented in 1951 *before The Institution of Engineers and Shipbuilders in Scotland.*

Got a tough tubing connection job?...

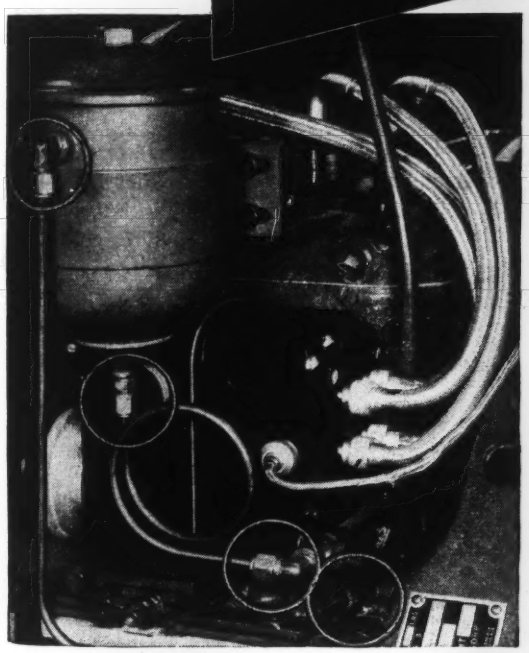
IMPERIAL FLEX FITTINGS

May Be the Answer

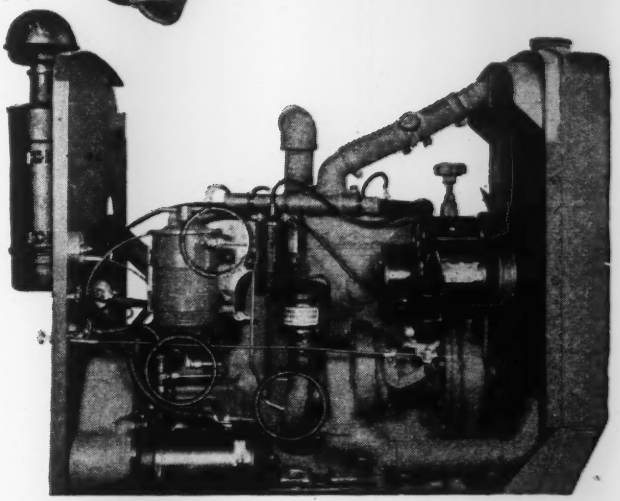


The tube coupling with vibration and shock absorbing sleeve.

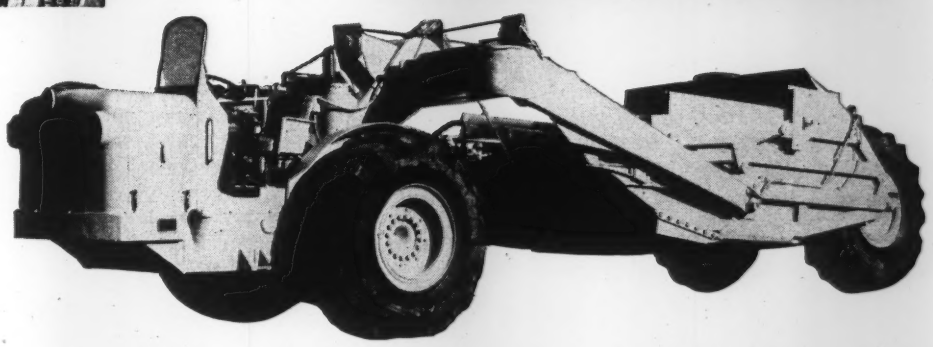
This Elastic Sleeve in Flex Fittings Absorbs Vibration and Shock . . . permits tubing to flex and at the same time assures a positive pressure tight seal. Flex Fittings are used as standard equipment on this heavy-duty engine.



Flex Fittings make joints virtually indestructible by VIBRATION . . . withstand SHOCK and MINOR TUBE MOVEMENT



Flex Fittings, circled on this engine, are very easy to install . . . simply slip nut and Flex sleeve over tubing . . . insert tubing into body as far as it will go and tighten nut—that's all.



Flex Fittings Can Be Used With All Kinds of Tubing

Imperial Catalog 344 gives you complete information on Flex Fittings. Ask for your copy.

Whether it's earth movers (illustrated), tractors, diesel engines, heavy power equipment or machinery, Flex Fittings will do the job. They have been thoroughly proved by extensive use.

THE IMPERIAL BRASS MANUFACTURING COMPANY
513 S. RACINE AVE., CHICAGO 7, ILL.

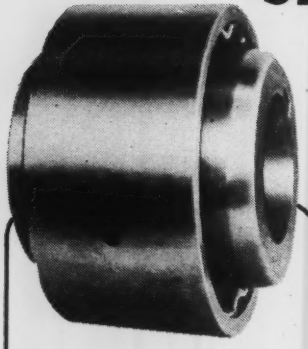
IMPERIAL

PIONEERS IN TUBE FITTINGS AND TUBE WORKING TOOLS

Sier-Bath
Flexible
GEAR COUPLINGS...

...Now Used on
SPENCER TURBO-COMPRESSORS
Size 7/8 Sier-Bath Coupling connecting the 5 HP, 3500 RPM motor with the compressor fan of a Spencer Turbo-Compressor, rated 450 CFM at 24 oz. pressure.

NEW, REVOLUTIONARY, Sier-Bath COUPLINGS:

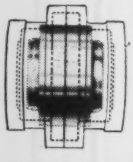


- Allow More Compact Designs
- Reduce Assembly Time
- Slash Down-Time
- Cut Equipment Wear

ONLY 7 PARTS—

ASSEMBLED, UNCOUPLED IN SECONDS!

3/5 USUAL SIZE!
1/2 USUAL WEIGHT!



Sier-Bath Gear Coupling compared with two major conventional types of same shaft size, HP rating.

Join the fast-growing list of machinery manufacturers and users now capitalizing on these advantages. Sier-Bath Couplings *eliminate* nuts, bolts, flanges—require no torque wrenches or other special tools. Assembly is accomplished by hand—uncoupling requires only a screw driver. Alignment checks are fast, simple—and the units connected can be run separately by simply sliding the one-piece sleeve over the opposite hub. Corrosion-proof . . . safer for men and machines . . . longer, trouble-free life . . . Sier-Bath Coupling cut costs, do the job better! DISTRIBUTORS IN PRINCIPAL CITIES.

WRITE FOR BULLETIN—gives installation photos, advantages, specs for standard, vertical mill motor and floating shaft types—sizes from 7/8 to 6, HP 4 to 550. (Special sizes and types on request.)

Sier-Bath GEAR and PUMP CO., Inc.
Founded 1905 Member A.G.M.A.
9245 HUDSON BLVD., NORTH BERGEN, NEW JERSEY

Also Manufacturers of Precision Gears and Screw and Gearex Rotary Pumps.

News
OF MANUFACTURERS

PLANS for the construction of a new $2,000,000 Haskell Laboratory of Industrial Toxicology near Newark, Del., were announced recently by **E. I. du Pont de Nemours and Co. Inc.**, Wilmington, Del. Enlarged facilities will be provided for the company's industrial toxicology laboratory which has been located at the experimental station in Wilmington since 1935. The Haskell Laboratory tests Du Pont products and manufacturing processes to eliminate potential hazards to employees and customers.

◆

The boards of directors of the **Whirlpool Corp.**, St. Joseph, Mich., and the **Clyde Porcelain Steel Corp.**, Clyde, O., have approved a merger of the two corporations. This merger will permit Whirlpool to utilize the more than 400,000 sq ft of manufacturing and warehouse area in the Clyde plant.

◆

Bimetallic pistons for automotive engines will be produced in Australia by the **Rolloy Piston Co. Pty. Ltd.** of Port Melbourne, under a license agreement with the Al-Fin Div. of the **Fairchild Engine and Airplane Corp.**, Farmingdale, L. I., N. Y. Rolloy has obtained exclusive rights for the manufacture in Australia of bimetallic pistons using the patented Al-Fin process and under its license will also manufacture bimetallic brake drums, sleeve bearings and bushings, timing gears, and cylinder barrels.

◆

General Electric Co., Schenectady, N. Y., has announced the expansion of its aviation equipment business to include a new operation for the design, manufacture and sale of turbine-driven accessories for jet engines and aircraft. Included among the products which are now being produced or developed by this new Accessory Turbine unit are turbosuperchargers and impellers, jet engine starters, turbine-driven fuel pumps, and air-turbine drives for alternators and

hydraulic pumps. Headquarters for commercial, engineering and manufacturing activities are at the company's River Works plant in Lynn, Mass., under the direction of J. P. Turner Jr.

♦

Surface components for the F-84 Thunderjet will be produced in quantity by the **Goodyear Aircraft Corp.**, Akron, O. Under terms of a subcontract with the **Republic Aviation Corp.**, Farmingdale, L. I., N. Y., Goodyear will manufacture horizontal stabilizers and elevators for the Thunderjet.

♦

Acheson Industries Inc., New York, has acquired the properties of the Peerless Printing Ink Co. and the Synthetic Lacquer & Varnish Co., adjacent plants in Philadelphia. The two properties, which will be combined and operated as **Peerless Printing Ink Co.**, were bought to permit the immediate expansion of activities in pigment dispersions, currently in demand because of the growth of the plastics and surface coating industries.

♦

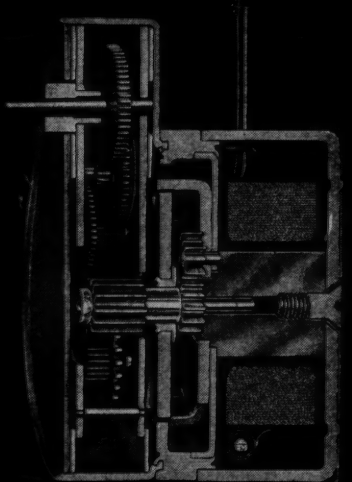
Expanded production of magnesium and aluminum castings will result from the opening of a new plant by **Castalloy Co.** in Natick, Mass. With a monthly capacity of 60,000 lb of finished castings, the plant has complete equipment for casting, finishing, heat treating, testing and X-raying. The company will specialize in producing magnesium castings for aircraft frames, jet engines, electrical and electronic parts, and radar components.

♦

Cambridge Corp., Cambridge, Mass., has established a mechanical division for the handling of a large-scale development and manufacturing program in the extreme low-temperature field. **Carrier Corp.**, Syracuse, N. Y., and **Arthur D. Little Inc.**, Cambridge, Mass., are joint owners of Cambridge Corp., which was formed last year to combine special aspects of the commercial, manufacturing, research and technical experience of the parent organizations. Manufacturing facilities and headquarters of the new division are located

SYNCHRONOUS TIMING MOTORS

Cramer



Dependable, constant speed performance with exceptionally high torque make the Cramer Type SX Permanent Magnet Synchronous Motor your best possible choice for instrument and control applications. A thoroughly engineered product . . . produced under skilled technical supervision . . . and proved in years of field service . . . Cramer Type SX Motors meet a wide range of specifications with clearly stated performance characteristics.

Torque 30 in. oz. at 1 r.p.m. Response so fast that motors reach synchronous speed in ½ to 2 cycles, stop within one pole of motion (1 60 sec.) on 240 r.p.m. rotor shaft.

Available with standard gear trains from 60 r.p.m. through 1 24 r.p.h. for 25, 50 and 60 cy. Also available in clutch type, chart drive and reversible units. (Patented controlled rotation either clockwise, counterclockwise or dual. Replaceable coils. U. L. approved.) Send for technical bulletins (giving complete details and specifications.)

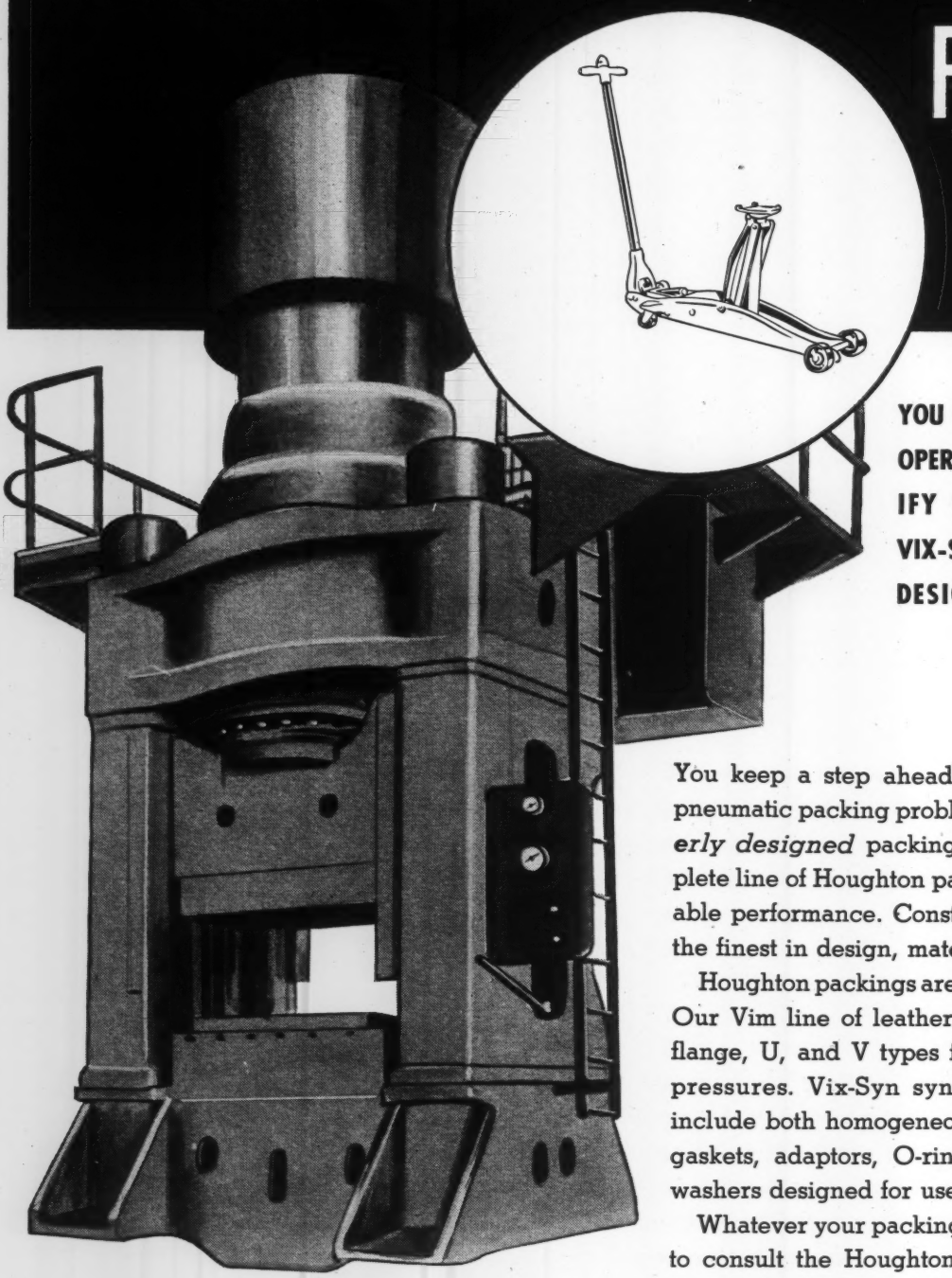
the R. W. CRAMER COMPANY, INC.

BOX 6, CENTERBROOK, CONN.

Builders of dependable timing devices for more than 25 years.

INTERVAL TIMERS • TIME DELAY RELAYS • RESET TIMERS • CYCLE TIMERS
PULSE TIMERS • RUNNING TIME METERS • PERCENTAGE TIMERS • SYNCHRONOUS MOTORS

NEITHER ONE PACKINGS



YOU CAN COUNT ON EFFICIENT OPERATION WHEN YOU SPECIFY HOUGHTON VIM AND VIX-SYN PACKINGS...THEY'RE DESIGN-ENGINEERED TO FIT!

You keep a step ahead of many hydraulic and pneumatic packing problems when you use *properly designed* packings. Each one of the complete line of Houghton packings will give you reliable performance. Constant research guarantees the finest in design, materials and craftsmanship.

Houghton packings are available for every need. Our Vim line of leather packings includes cup, flange, U, and V types for oil, air, water or gas pressures. Vix-Syn synthetic rubber packings include both homogeneous and fabricated types, gaskets, adaptors, O-rings and leather back-up washers designed for use with them.

Whatever your packing problem, it will pay you to consult the Houghton Man. The engineering service he offers can be valuable to you. Write or call E. F. Houghton & Co., Philadelphia 33, Pa.

WRITE TODAY FOR THIS BOOK

Write for latest edition of "Packing Standards"—the Houghton book accepted as standard by industry. Mailed without cost to you.

VIM and VIX-SYN PACKINGS products of...

E. F. HOUGHTON & CO.

PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

Ready to give you on-the-job service...

in Somerville, Mass. Facilities and personnel will be devoted to the development and custom production of specialized equipment required by manufacturers, government agencies and laboratories.

♦

Beckman & Whitley Inc., San Carlos, Calif., instrument engineering organization, has established a new guided missile products division. Initial emphasis of the division will be directed toward design consultation and manufacturing of explosives-actuated devices.

♦

Completion of an addition to the **Federal Tool and Manufacturing Co.** plant at Minneapolis has been announced. The new 12,000 sq ft addition will be devoted to an expanded die department, and the space formerly occupied by the die department will be used for production and for additional production equipment which is now being installed.

♦

The Babcock & Wilcox Co., New York, has begun construction of a new plant in Paris, Tex. The plant will manufacture components for large utility and industrial boilers and will also assemble smaller FM boilers, a new integral unit recently designed by the company.

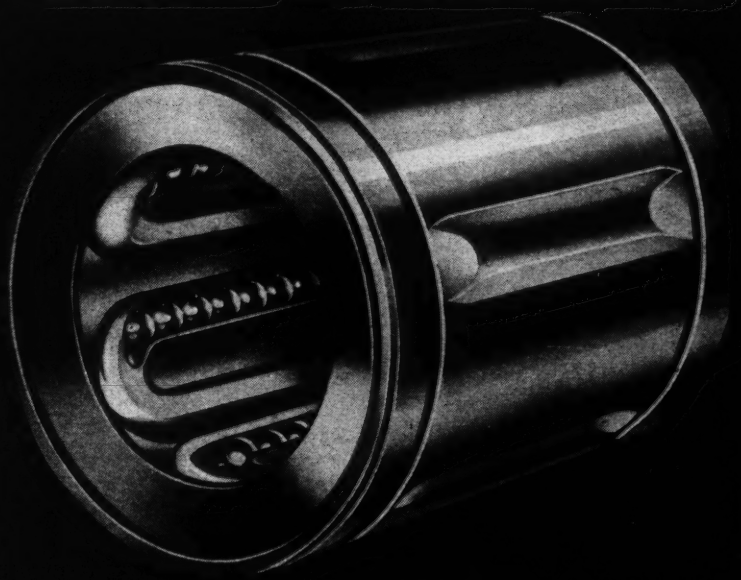
♦

Executive offices of the **Doehler-Jarvis Corp.** have been moved to a new office building adjacent to the corporation's plant in Toledo, O. However, H. H. Doehler, honorary chairman of the board, will retain his headquarters at the former New York address, 386 Fourth Ave.

♦

Borg-Warner Corp., Chicago, has established a products development laboratory in Detroit as a separate division responsible for carrying both defense and civilian items from the invention stage to actual production. The laboratory, occupying 20,000 sq ft of floor space, has been equipped with electric and gas - driven dynamometers and other testing devices, as well as with modern machine shop tools. The development of new products for military use and the improvement of automatic transmissions

BALL BUSHING



The BALL BEARING for your

LINEAR MOTIONS

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers have solved this problem by application of the Precision Series A or Low-Cost Series B BALL BUSHINGS.

Alert designers can now make tremendous improvements in their products by using BALL BUSHINGS on guide rods, reciprocating shafts, push-pull actions, or for support of any mechanism that is moved or shifted in a straight line.

Improve your product. Up-date your design and performance with BALL BUSHINGS!

Now manufactured for 1/4", 1/2", 3/4", 1", 1 1/2" and 2 1/2" shaft diameters.

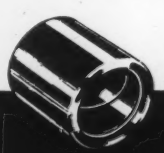
LOW FRICTION • LOW MAINTENANCE
ELIMINATES BINDING AND CHATTER
SOLVES SLIDING LUBRICATION PROBLEMS
LONG LIFE • LASTING ALIGNMENT

Progressive Manufacturers Use Ball Bushings
—A Major Improvement at a Minor Cost

THOMSON INDUSTRIES, Inc.

Dept. E MANHASSET, NEW YORK

Write for descriptive literature and the name of our representative in your city.



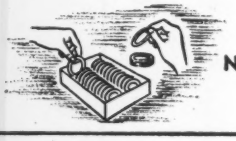
Also manufacturers of NYLINED Bearings — DuPont NYLON within a metal sleeve—for rotation and reciprocation.

LAMINATED SHIMS

SIMPLY PEEL FOR ADJUSTMENT

Shims stamped from brass or steel LAMINUM® *look and act like solid metal but they peel off in .002" (or .003") layers.*

Provide great accuracy yet allow easy machining tolerances



No counting

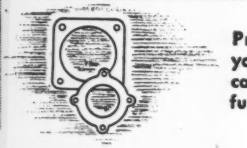
Speed production by simplifying your spacing adjustments

No stacking

Reduce lathe time; no standby machine required during assembly

No miking

Adjustments right at the job by peeling laminations with a penknife



Precision cut to your exact specifications, with careful quality control

URGENT! Save production time! Shims are more important now than ever! *SEND TODAY for our Engineering Data File*

LAMINUM

THE SOLID SHIM THAT FOR ADJUSTMENT

LAMINATED SHIM COMPANY, Inc.

1204 UNION STREET GLENBROOK, CONN.

CUSTOM SHIMS STAMPINGS SHIM STOCK

are the projects which are being given immediate attention by the laboratory's staff.

♦

Colonial Bushings Inc. has completed construction of its new, larger plant at 31780 Groesbeck Highway, Fraser, Mich. In addition to machinery transferred from the former plant, new equipment has been installed to increase productive capacity.

♦

The transformer division of **Westinghouse Electric Corp.**, Pittsburgh, has begun producing Hipersil wound cores for electronic transformers at two recently leased plants at Greenville, Pa., and Lima, O. The leasing of these two plants releases approximately 30,000 sq ft of space for the production of distribution transformers at the division's main plant at Sharon, Pa.

♦

The Cleveland Graphite Bronze Co., Cleveland, has acquired ownership of **The Brush Development Co.**, Cleveland research and manufacturing organization active in the fields of electronics and technical instruments. The Brush organization manufactures a variety of products used in recording and reproducing sound, including crystals, industrial instruments, and magnetic sound recorders.

♦

To be operated as a wholly-owned subsidiary, **Metalmold Corp.**, Derby, Conn., was recently acquired by **Arwood Precision Casting Corp.**, Brooklyn, N. Y.

♦

National Malleable and Steel Castings Co., Cleveland, has purchased **Capitol Foundry Co.**, Phoenix, Ariz. Capitol's subsidiary, **Arizona Iron Works**, is included in the purchase. These two companies will be operated as subsidiaries of National Malleable. A $1,500,000 expansion program will be undertaken, including the installation of electric melting furnaces and other equipment to produce cast steel grinding balls and to expand production of miscellaneous steel, iron, and alloy castings. At present Capitol produces white iron grinding balls for the ball mills at copper concentrating plants.

CUT COSTS

with the Original Mead

MIDGET AIR CLAMP

(Spring Return Air Cylinder)

In assembly jigs and other multiple applications, this new, low cost pressure unit saves countless man-hours. As a work-ejector in many fixtures, it is unexcelled.

Advantages over mechanical clamps

1 **All Air Clamps** in any set-up can be operated by a single master valve—the "lock-up" and release of assemblies is instantaneous.

2 **May be installed in cramped corners** difficult to reach with bulky mechanical clamps. Mead Midget is the most compact air cylinder, for its power, on the market.

3 **Equal ram pressure at any point** along stroke, making special, delicate adjustments unnecessary.

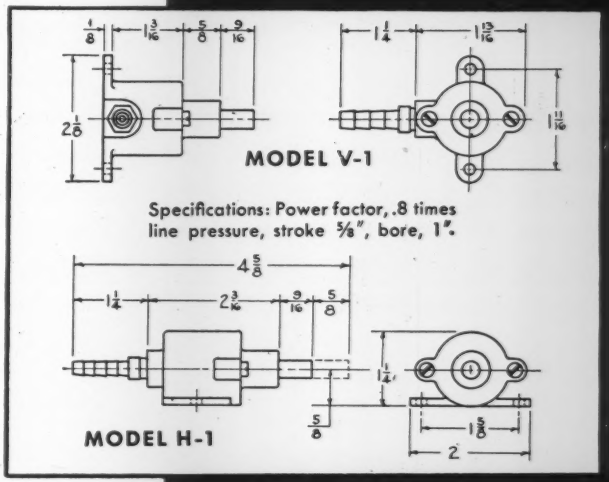
4 **Independent group control.** Any desired group of "Midgets" can be controlled independently of any other group in an assembly—as where primary members of the fixture must be locked up before the secondary members.

5 **Facilitates delicate drill operations.** Air Clamps actuated by foot control valves leave operator's hands free to handle the work pieces.

Send for all the interesting facts on these time-tested, superior Midget Air Clamps.

MEAD SPECIALTIES COMPANY

4114 North Knox Avenue • Dept. MD-42 • Chicago 41, Illinois



IMMEDIATE DELIVERY

Single-acting cylinders delivered from stock; double-acting in a few days.

***New* MEAD INDUSTRIAL AIR POWER CATALOG**

MEAD

Air Operated Devices

Memo Coupon

MEAD SPECIALTIES CO.

4114 N. Knox Ave., DEPT MD-42, Chicago 41, Ill.

Send free copy of new, colored MEAD INDUSTRIAL AIR POWER CATALOG describing the complete line of famous Mead air-operated devices.

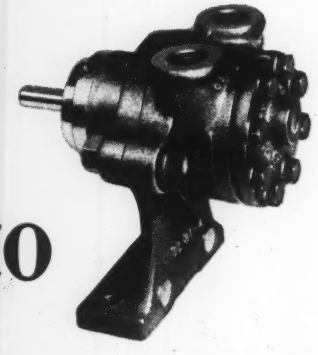
Name_____

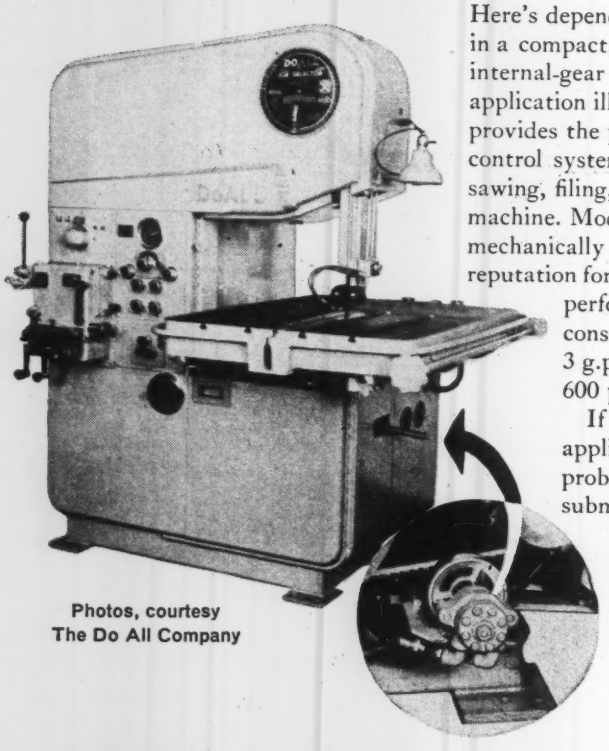
Company_____

Address_____

City_____ Zone____ State_____

You can depend on TUTHILL Model L Pumps for the power to feed and control equipment like this





Photos, courtesy
The Do All Company

Here's dependable hydraulic power in a compact, positive displacement internal-gear rotary pump. In the application illustrated, Tuthill Model LK provides the power for the feed and control systems on this multi-purpose sawing, filing, grinding and polishing machine. Model LK is a ball-bearing, mechanically sealed pump with a reputation for quiet, leak-free, dependable performance and low power consumption. Capacities up to 3 g.p.m. and pressures to 600 p.s.i.

If you have a similar application, or any pumping problem, you are invited to submit a sketch for recommendations without obligation. In any event, it will pay you to write for the complete details on Tuthill Model L pumps.

25th Anniversary — TUTHILL — PUMPS FOR THE PURPOSE

Tuthill Pump Company

939 East 95th Street, Chicago 19, Illinois

Association ACTIVITIES

AT THE 54th Annnual Meeting of the **American Ceramic Society** to be held in Pittsburgh, April 27-May 1, Ferro Corp., Cleveland, Ohio, will sponsor a student contest in porcelain enameling. Prizes totaling $1000 will be awarded to students, graduate and undergraduate, in ceramic schools in the United States. Contest judges are Charles S. Pearce, general secretary of the Society; Edward Mackasek, Porcelain Enamel Institute; and B. J. Sweo, Ferro Corp.

♦

Newly elected at the **Steel Founders' Society 50th Anniversary** Meeting were the following officers for 1952: president, H. A. Forsberg, Continental Foundry & Machine Co.; vice president, Carl F. Barchfeld, Commercial Steel Casting Co.; and director and executive committee member, Arthur S. Breithaupt, Dodge Steel Co.

The following awards were also presented at this meeting.

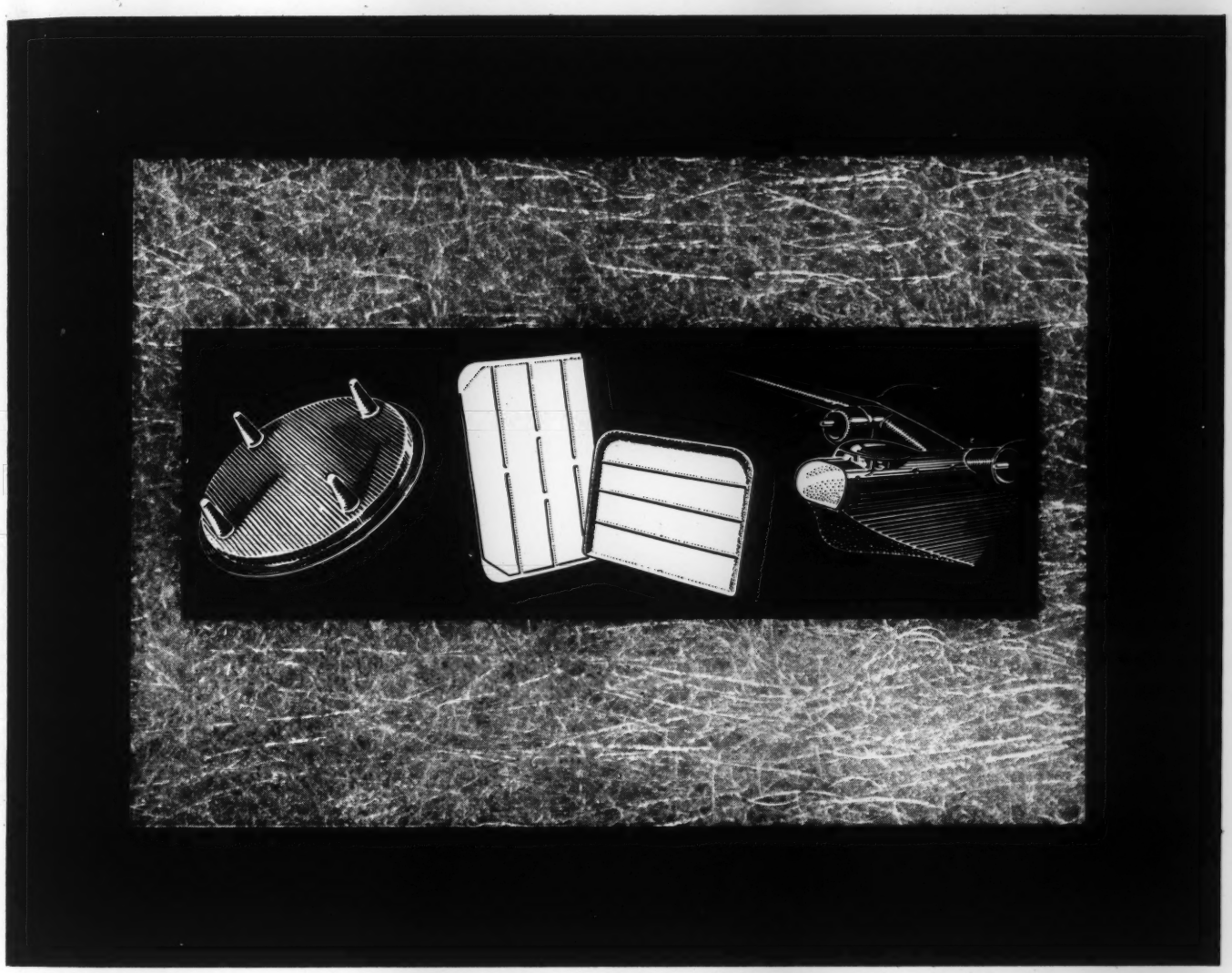
Lorenz Memorial Gold Medal to James Suttie, American Steel Foundries, for "unselfish contribution of time and effort over a long period. . . ."

Technical and Operating Gold Medal for 1951 to Luther A. Kleber, General Steel Castings Corp. for "an outstanding and unselfish job for the betterment of the steel casting industry. . . ."

Annual Steel Foundry Facts Award to Harold H. Johnson, National Malleable and Steel Casting Co., for "excellence of material published in the Society's technical publication."

♦

Nominations are now being received by the **Society of Naval Architects and Marine Engineers**, 29 W. 39th St., New York 18, N. Y., for three graduate scholarships which are being offered this year. These three scholarships, each covering the cost of tuition at the college selected, plus $1600 for living expenses, are for post-



STRUCTURAL PLASTICS YOU CAN [redacted] ON

BAKELITE Polyester Resins constitute a fast-growing branch of the plastics industry. These resins are used in the production of reinforced plastics, chiefly with glass fiber mat or woven glass cloth. When properly formulated and applied they produce truly structural plastics with high strength-weight ratios that compare favorably with aluminum and steel. Present applications include boat hulls, refrigerator panels, radar housings, tote boxes, luggage.

In general, BAKELITE Polyester Resins provide excellent resistance to moisture, many chemicals, heat and cold. Certain types have excellent electrical characteristics including electrical "transparency" for radar housings. Another type can be cast into strong transparent solids. Another type is highly flexible and is used to impart added toughness to the other Polyester Resins. Inorganic fillers can be incorporated in certain of these resins to reduce costs and to minimize cracking and crazing.

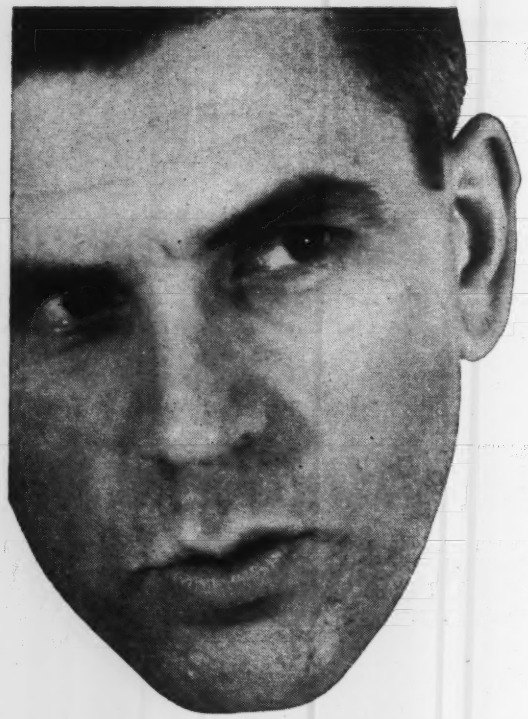
BAKELITE Polyester Resins are "tailor-made" to meet widely different chemical, physical, and electrical requirements. BAKELITE engineers will gladly assist you in choosing the right resins or combinations of resins for the intended end use. Write Dept. DK-52 for technical assistance and for latest data on the principal BAKELITE Polyester Resins now being marketed.

Visit BAKELITE'S EXHIBIT Booth 412
National Packaging Exposition
Convention Hall, Atlantic City April 1-4

BAKELITE
TRADE-MARK
POLYESTER RESINS

TRADE MARK

BAKELITE COMPANY
A Division of
Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N. Y.
In Canada:
Bakelite Company (Canada) Ltd., Belleville, Ont.



how much is bearing trouble affecting your products' reputation?

It can you know — and yet it is so easy to avoid machinery inefficiencies traceable to bearing failures. Just be sure to specify one of the MULTIROL full type roller bearing series. Each is designed for a specific kind of service and has proven ability to carry greater loads longer with more precision and less maintenance. Their dependability will help keep your machinery at its peak. Select one of the following types and write today for more details in the new McGill Bearing Catalog No. 52.

graduate study leading to a degree of Master of Science in Naval Architecture or Master of Science in Marine Engineering. The scholarships will be available for the college year commencing in the fall of 1952.

♦

Harold V. Atnip, Body Design Department of Chrysler Corporation's Engineering Division, has been elected and installed as president of the **American Society of Body Engineers.** Other officers installed were: vice president, Kenneth E. Coppock, Fisher Body; secretary, Glen F. Doyle, Ford Motor Co.; and treasurer, Vernon F. Groeteka, Fisher Body.

The board of trustees includes: Harry G. Garman, General Motors Corp.; I. Louis Carron, Carron and Company; Gordon J. Lawton, Briggs Mfg. Co.; Charles L. Waterhouse, Jr. and John C. Widman, Ford Motor Co.; Edward I. Pangborn, Chrysler Corp.; and Lynn A. Fill, Motor Products Corp.

♦

The **Resistance Welder Manufacturers Association** announces the election of J. R. Barefoot, Jr., The Federal Machine and Welder Co., as president for the coming year.

♦

The Applied Mechanics Division of the **American Society of Mechanical Engineers** has announced a Shock and Vibration Instrumentation Symposium to be held during the summer meeting, June 19-21. Papers will be presented on survey and history, one-degree-of-freedom instruments, sources of error and secondary effects, peak reading gages, calibration, and applications. It is expected that the symposium papers and discussion will be published in a single volume which will present the current state of knowledge on shock and vibration instrumentation.

♦

Stewart Pike of Philadelphia was elected National president of the **Industrial Designers Institute** at the semiannual meeting of the National Board of Trustees. Other officers elected were: vice president, Robert L. Gruen, New York; secretary, Henry Hagert, Philadelphia; and treasurer, Kurt Versen, Englewood, N. J.

COMPETITION KEEN?

Can't find ways to cut production time?

THEN YOU HAVEN'T USED

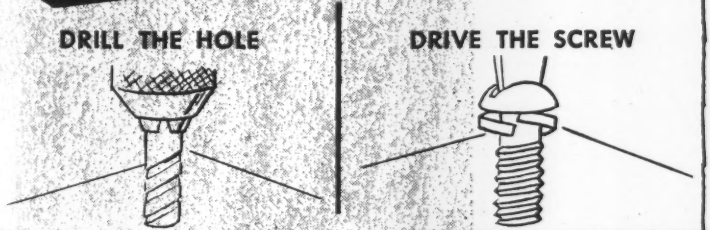
Reliance "threadcutting"

(and cost cutting)

Springtites and Sems!

Reliance "thread-cutting" Springtites and Sems can answer both of these problems. First, by giving you tighter and longer-lived assemblies (improved product quality) and second, by cutting out costly old-fashioned tapping operations that add hours to factory costs. Write today for samples and let Reliance "thread-cutting" Springtites and Sems reduce your production costs.

2 Simple Operations

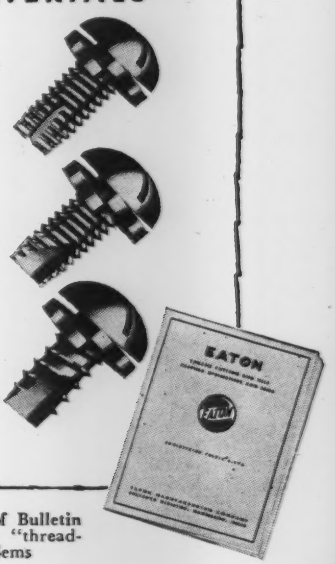


FOR ALL MATERIALS

TYPE 1 FOR STEEL
Ideal for sheet steels and stainless. Standard machine screw threads plus Reliance lock washer for stronger, tighter fastenings.

TYPE 23
FOR DIE CASTINGS
Specially designed for die castings and metals that powder when driven. Standard machine screw thread and Reliance lock washer for exceptional tightness.

TYPE 25
For every type of Plastics assembly, Type 25 features spaced threads to keep stripping to a minimum.



Write today for your free copy of Bulletin S-49A that describes Reliance "thread-cutting" Springtites and Sems

Reliance "Thread-Cutting" Springtites and Sems

EATON MANUFACTURING COMPANY, RELIANCE DIVISION

OFFICE AND PLANTS • MASSILLON, OHIO

SALES OFFICES: NEW YORK • CLEVELAND • DETROIT • CHICAGO • ST. LOUIS
SAN FRANCISCO • MONTREAL

FOR RESISTANCE TYPE WELDERS • FOR AIR VISES • FOR MACHINE FEEDS • FOR PRESS BRAKES • FOR STEEL MILL EQUIPMENT • FOR AIR CLAMPS • FOR AUTOMATION • FOR LATHE CHUCKS •

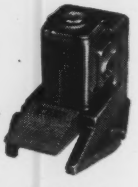
You'll find Air Valves for every job in this

COMPLETE

MAC

Air Valve Line

Solenoid In-Line Valve


Foot Valve

Solenoid Pilot Valve

Hand Valve

Solenoid Valve

Double Solenoid Valve

Pilot Controlled Valve

Cam Valve

For Trigger-Quick Control of All Air-Operated Equipment

★

Straightway, 3 way, 4 way

★

Sizes: ¼" thru ¾"

EFFICIENT! Full flow design . . . plus simplified construction with only one moving part . . . add up to more dependable performance, longer life, reduced maintenance.

COMPACT! The compact design of MAC valves makes them especially adaptable for installations where space is limited.

ECONOMICAL! Yes . . . with all their extra advantages, MAC valves are actually priced *lower* than many ordinary air valves. Here's an investment that really pays off!

MAC MECHANICAL AIR CONTROLS

BOX 5171 SOUTHFIELD STATION, DETROIT 35, MICH.

Write For Free Catalog No. 52-C

SALES AND SERVICE

Personnel

ASSOCIATED with the company for more than eleven years, **J. R. Lewis** has been appointed general sales manager of Quaker Rubber Corp., division of H. K. Porter Co. Inc., Philadelphia. Mr. Lewis has served as Philadelphia district sales manager, assistant sales manager, and assistant general sales manager. In his new position he will be in complete charge of the sales organization of the company.

♦

Irwin Weinstein has joined the staff of Electronic Devices Inc., Brooklyn, N. Y., as assistant sales manager. Mr. Weinstein has engaged in the design and sale of many types of rectifiers used both in commercial production and governmental work.

♦

Robert B. Coleman was recently appointed to the newly created post of manager of sales operations for Lamson Corp., Syracuse, N. Y. He will be responsible for carrying out sales policy, plans and field programs.

♦

Cincinnati Lathe & Tool Co. has announced the appointment of **Dave Wallace** as assistant sales manager. Mr. Wallace formerly represented the firm in the central states, with headquarters in Chicago. In his new position he will work out of the company's main office in Cincinnati.

♦

John J. Fitzsimmons has been appointed to the sales engineering staff of Illinois Tool Works, Chicago, to serve cutting tool users in the Detroit area. He will work under the direction of the company's Detroit district sales manager, **E. D. Wiard.**

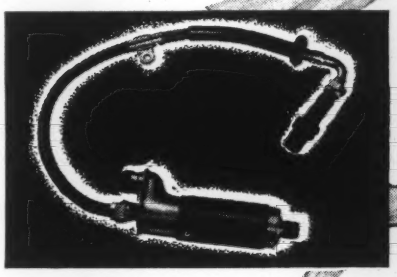
♦

Hyatt Bearings Div. of General Motors Corp., Harrison, N. J., recently announced that **Harry J. Conlan** has been transferred to the Pittsburgh office as assistant di-

SILICONE PROGRESS

TO HARNESS HORSEPOWER—

use G-E SILICONES for insulation



Exceptional heat resistance (up to 500 F) makes G-E silicone rubber ideal for insulation in harnesses for aircraft and automotive ignition systems.

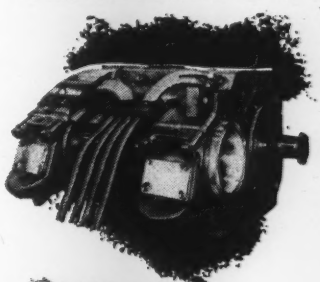
Now you can design electrical components which will operate over a wide temperature range—thanks to the unusual properties imparted to these products by General Electric silicones. Substantial reduction (25-40% on an average) in size and weight of transformers, generators, and other electrical equipment is also possible when G-E silicones are used in the insulation.

Have you considered G-E silicones in your products? Perhaps you need a resin or a varnish for bonding or impregnating purposes. Perhaps you need a resilient material for gaskets or sheeting. Or do you need a fluid to impart water-repellency to masonry surfaces? Whatever your need, it will pay you to investigate G-E silicones. You may find a ready answer to your problem.

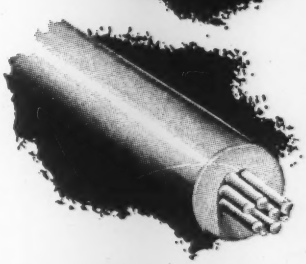
G-E *SILICONES FIT INTO YOUR FUTURE*

GENERAL ELECTRIC

OTHER EXAMPLES OF G-E SILICONE INSULATION



Save rewind costs— on heavy-duty motors because G-E silicones in "Class H" insulation withstand high heat and mechanical stress.



Higher operating temperatures for motors, generators, and transformers require flexible lead wires insulated with G-E silicones.

Want more information? More examples of G-E silicone developments of importance to industry are to be found in *The Silicone Story*. Send the coupon today for *your* free copy.

FREE

General Electric Company
Section C-2
Waterford, New York

Please send me my free copy of *The Silicone Story*.

Name _____

Firm _____

Street _____

City _____ Zone _____ State _____

(In Canada, mail to Canadian General Electric Company, Ltd., Toronto.)

Platecoils are not only more efficient but they save time for many departments when used instead of pipe coils in original equipment. For instance, Peters-Dalton, Inc., Detroit, Michigan, has found that use of Platecoils has simplified engineering and estimating. Considerable time is saved in the planning stage by referring to the standard charts of sizes and capacities.

They have found, too, it is less costly to buy Platecoils than to fabricate pipe coils in their own plant. The Platecoils can be installed in a fraction of the time as they do not require the complicated racks and brackets needed for pipe coils.

In addition, because the Platecoils are more efficient, smaller size Platecoils can be used to heat a given tank. This means that extra tank capacity is provided without increasing tank size.

Why pay the high cost of pipe coils when you can heat or cool more efficiently at lower cost, using Platecoils. Ask Platecoil engineers to help you with your next heat transfer problem. There is no obligation. Send too for your copy of bulletin No. P71.

vision engineer for the central sales territory. He formerly served in the same capacity in the eastern sales division. At the same time **Rudolph D. Silvern** and **Henry Ned Meyer Jr.** were added to the force of sales engineers in Hyatt's Chicago office.

♦

E. B. Wiggins Oil Tool Co., Los Angeles, recently appointed **Rod Strouse** as sales engineer for aircraft.

♦

To serve the state of Missouri from headquarters in St. Louis, **Karl H. Dressel** has been promoted to field engineer for the Republic Rubber Div., Lee Rubber & Tire Corp., Youngstown, O. Mr. Dressel has been associated with the division since 1950. Also announced recently by Republic was the appointment of **Alfred W. Crew** as a field engineer, with headquarters in Charleston, W. Va.

♦

Robert N. Nelson, formerly assistant sales manager, has been promoted to the position of sales manager of the pneumatic division of Sundstrand Machine Tool Co., Rockford, Ill. Mr. Nelson joined the company in 1946 as a sales engineer in the pneumatic division and was advanced to the post of assistant sales manager earlier this year.

♦

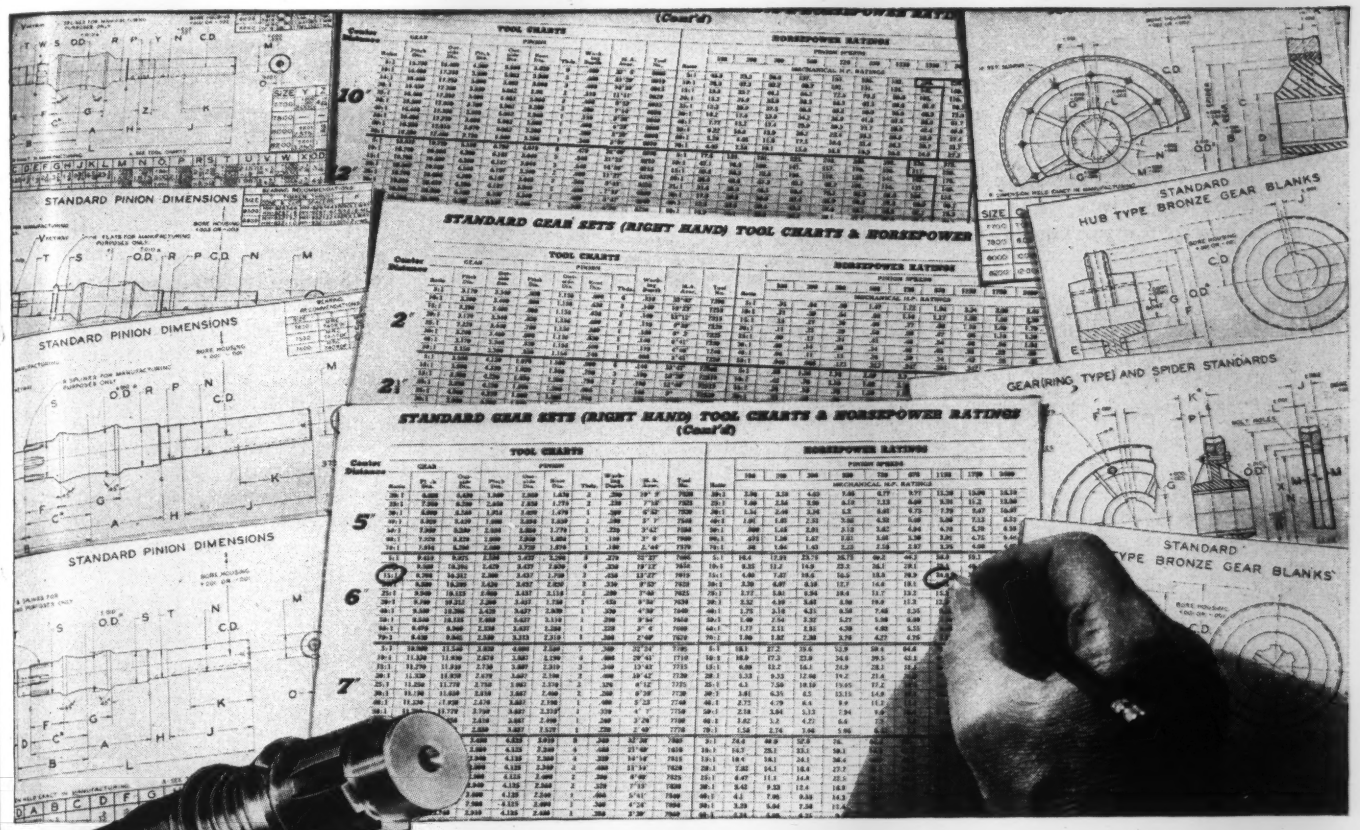
Frank Ingham, who has served for several years as a sales representative, was recently appointed manager of the Cleveland office of Atlas Chain & Mfg. Co., Philadelphia.

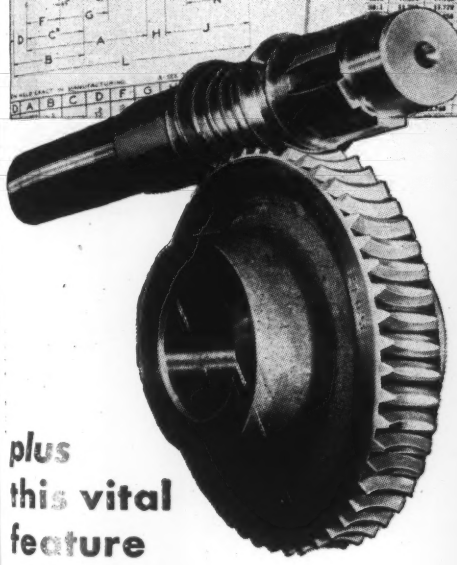
♦

General manager of the company's cellophane tape division since 1941, vice president **John A. Borden** was recently named sales and marketing consultant for all tapes produced by Minnesota Mining and Mfg. Co., St. Paul.

♦

Three promotions were announced recently by Magnesium Co. of America, East Chicago, Ind., fabricator of wrought magnesium products. **Dennis E. Harvey,** who has been associated with the company since 1947, was elected a vice president. He will head the Wash-





Specify STANDARD Cone-Drive Gears and get all these advantages

plus this vital feature

Standard *Cone-Drive gears and worms are carried in stock. Cone-Drive gears are noted for their long life—BUT if a failure should occur at any time, replacement gears and worms are available without delay.*

Ask for Catalog No. 700

Lower Cost—due to smaller size of gears and housings, mass production of worm and gear blanks, etc.

Compactness—due to distribution of load over greater contact area, reducing unit pressures. As a result, gear sets can have smaller center distances, enclosures can be smaller, etc.

Less Weight—due to smaller center distances for a given horsepower or torque. Other types of gearing weigh up to 3 times as much for the same horsepower transmitted.

Greater Smoothness—because Cone-Drive gears have more teeth in continuous contact than other forms of gearing.

Wide Range of Sizes—Center distances from 2" to 18" provide horsepower ratings from fractional up to 800 horsepower. Ratios range from 5/1 to 70/1.

CONE-DRIVE GEARS
Division, Michigan Tool Company
DOUBLE ENVELOPING GEAR SETS & SPEED REDUCERS
7171 E. McNichols Road • Detroit 12, Michigan

MEASURE IN MICROINCHES RMS

By 3 to 2
it's a shop tool!

The Profilometer at National

At the National Cash Register Company plant in Dayton, Ohio, Profilometers used as shop tools outnumber those in inspection three to two.

For example, the Profilometer shown is on *actual* production work in a machining department. Here, the surface finish of a bearing in a side frame of a cash register is being checked. Reaming specifications call for the bearing surface to have a rating of 20 microinches or less.

Other Profilometers are used as shop tools in two parts-machining departments. Still others are used in tool inspection and in investigation-inspection. The latter section—with the help of the Profilometer—determines if the engineering specifications for surface finish are being met.

Extreme accuracy has always been stressed in the more than 180,000 different parts that go to make up National Cash Register accounting machines and adding machines. Because of that policy, the National Cash Register Company was one of the original purchasers of a Profilometer. That investment has paid off many times.

If accuracy in surface roughness measurement is important in your plant, the Profilometer can give it to you.

To learn how the Profilometer can help cut costs in your production, write today for these free bulletins.

Profilometer is a registered trade name.

MICROMETRICAL
MANUFACTURING COMPANY
formerly PHYSICISTS RESEARCH COMPANY
Instrument Manufacturers
ANN ARBOR 13 MICHIGAN

ington, D. C., offices. **William Johansen,** former southwestern division manager, was appointed general sales manager and has been transferred to the company's general offices in East Chicago. **Charles J. Futterer,** formerly assistant to Mr. Johansen, is the new southwestern division manager, with headquarters in Houston, Tex.

♦

The board of directors of Homestead Valve Mfg. Co., Coraopolis, Pa., recently appointed **Don H. Krey** to the position of vice president in charge of sales.

♦

George E. Brown has been named as a sales engineer for graphite products by The United States Graphite Co., a division of The Wickes Corp. He will work out of the company's home office in Saginaw, Mich. Mr. Brown comes to his new position from the United States Steel Co.

♦

Formerly district manager in the eastern territory, **Henry M. Faulkner** was recently appointed southwest industrial territory manager for Allis-Chalmers Mfg. Co. His headquarters will be at the company's home office in Milwaukee.

♦

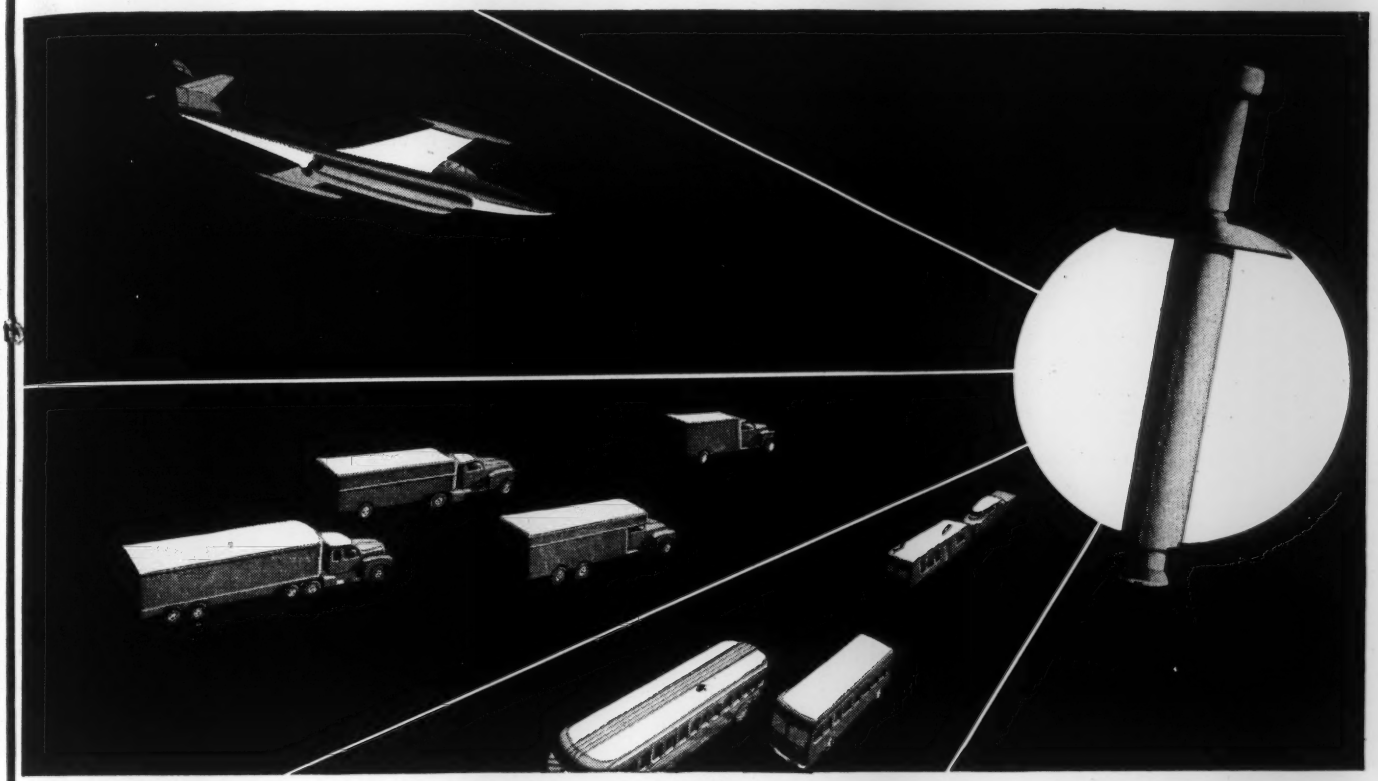
W. S. Andrews, who has served as Pittsburgh district sales manager for seven years, has been appointed New York district sales manager for Rockwell Mfg. Co., Pittsburgh.

♦

The appointment of **Robert F. Hodgson** to the position of vice president of Hydraulic Equipment Co., Cleveland, was announced recently. Formerly sales manager and chief engineer, Mr. Hodgson joined the firm in 1945 as a sales engineer.

♦

Wolverine Tube Div. of Calumet & Hecla Consolidated Copper Co., Detroit, recently announced several changes in its sales organization. **L. G. Fox,** formerly manager of wholesaler sales, has been appointed manager of sales service, and **S. C. Seekell,** who has been in charge of the Grand Rapids sales office, has been appointed manager of wholesaler sales. Both men will



How Cherry Rivets Bring Aircraft Construction to Trucks and Busses

There may not be much resemblance between a lumbering trailer truck and a sleek night fighter but many have a lot in common. When Cherry Blind Rivets are used in their assembly they are constructed quickly, with economy.

Long ago, the aviation industry came to realize it could speed plane production with big savings in unit costs by the use of these ingenious rivets which are applied from one side of the work, by one man, without bucking up. Their use has become standard in many aviation plants.

Now, the use of Cherry Rivets has spread to other industries. They make possible reduced assembly time and lower costs in construction of trucks, trailers, and busses, for example. This is true for several reasons.

Truck and trailer body builders find that plywood liners stay in place despite severe vibration when fastened permanently with these special blind rivets. In house trailers and insulated trucks, the use of Cherry *hollow* blind rivets provides breather holes in the double surface of the walls. This reduces condensation and increases vehicle life. In bus construction, metal surfaces are applied with ease in many hard-to-reach places because Cherry Rivets are installed by a pulling action, no bucking—no twisting—no exploding—no hammering is necessary.

These examples of how Cherry Rivets improve vehicle construction are typical of how many products are improved and assembly procedures speeded through use of Townsend fasteners and small parts.

Since 1816, Townsend has developed a tremendous fund of special knowledge about wire-drawing and cold-heading a variety of metals. During this time the company's line of products has expanded to include more than 10,000 standard and special items.

This is why designers, production engineers, and purchasing agents have come to know Townsend as a dependable source of supply. Why not find out how you can enjoy the benefits of Townsend experience and facilities? Write today.

Townsend

COMPANY • ESTABLISHED 1816

Sales Offices in Principal Cities

Plants—New Brighton, Pa. • Chicago 38, Ill.

Cherry Rivet Company Division, Los Angeles, Cal.

THE FASTENING AUTHORITY—Experience: *over 136 years*—**Capacity:** *sixty-million parts daily*—**Products:** *over ten-thousand types of solid rivets—cold-headed parts—Cherry Blind Rivets—self-tapping screws—tubular rivets—locknuts—special nails—formed wire parts.*

OVER ONE HUNDRED YEARS OF CONTINUOUS SERVICE. ROUNDS, SQUARES, FLATS, HEXAGONS, OCTAGONS

BILLETS AND FORGINGS FOR PRODUCTION, TOOL ROOM AND MAINTENANCE REQUIREMENTS

perhaps our experience can

STRETCH

your alloy steel supplies!

You have doubtless heard about "bar-stretchers." Have you ever seen one? Wheelock, Lovejoy has several – any one of which can help you stretch your alloy steel supply so that you can keep up your production schedules during this period of unavoidable shortages. Having been in the steel business for over 100 years, our staff of metallurgists is in a unique position to help solve your difficulties. Our "bar-stretchers" include suggestions for substitute grades – alternate methods of manufacture – varying your present methods of treatment – and many more!

A letter or phone call to your nearest Wheelock, Lovejoy warehouse will bring an experienced man to help you stretch your alloy steel supply.

And he will be delighted to be of service! *SCRAP is worth money, and every pound turned in means more steel for you – so get in the SCRAP!*

Write today for your FREE COPY of the Wheelock, Lovejoy Data Book, indicating your title and company identification. It contains complete technical information on grades, applications, physical properties, tests, heat treating, etc.

WHEELOCK, LOVEJOY & CO., INC.

Warehouse Service

CAMBRIDGE • CLEVELAND
CHICAGO • HILLSIDE, N. J.
DETROIT • BUFFALO
CINCINNATI

In Canada
SANDERSON-NEWBOULD, LTD., MONTREAL

HY-TEN *and* AISI

133 Sidney St., Cambridge 39, Mass. **and Cleveland • Chicago • Detroit Hillside, N. J. • Buffalo • Cincinnati**

make their headquarters at the company's general sales offices in Detroit. **J. A. Jolly** has been placed in charge of sales in western and northern Michigan and has been transferred from the Milwaukee sales office to replace Mr. Seekell in Grand Rapids. **D. M. Irwin**, who was formerly affiliated with Allis-Chalmers Mfg. Co., will be in charge of sales in the Milwaukee area.

♦

A. B. Hennessy Jr. was recently appointed district manager of sales in the Chicago area for the Summerill Tubing Co. Div. of Columbia Steel & Shafting Co., Pittsburgh.

♦

De Laval Steam Turbine Co., Trenton, N. J., recently appointed two new divisional sales managers. **J. H. Metzgar** was named sales manager of the standard products division, and **C. E. Cromwell** was appointed sales manager of the commercial division. Both men have served as sales engineers for De Laval, and Mr. Cromwell was district manager of the company's Detroit office from 1949-1951.

♦

John R. Hoover, newly elected president of B. F. Goodrich Chemical Co., Cleveland, has announced the election of **James C. Richards Jr.** as vice president of sales and the appointment of **Allyn I. Brandt** as general merchandising manager. Mr. Richards, who had been manager of international sales, succeeds Mr. Hoover as vice president. Mr. Brandt, former general sales manager, is assuming increased responsibilities in his new post.

♦

Formerly director of engineering and assistant to the vice president, **William H. Taylor** has been appointed general sales manager of Tinnerman Products Inc., Cleveland. Mr. Taylor has a background of approximately 25 years of sales, engineering, and sales management experience.

♦

Edward N. Cunningham was recently promoted to the position of assistant sales manager of Precision Rubber Products Corp., Dayton, O. Mr. Cunningham joined the firm's technical sales staff in January 1951.

FREE Cylinder Catalog and Templates offered by Ortman-Miller Co.

Book outlines several special features of O-M cylinders.

FREE

A new, 28 page catalog has just been released by the Ortman-Miller Machine Co. which gives complete engineering specifications, data on O-M's special internal locking system and special full listing of O-M parts. Prepared for designers and users of cylinders for any application, it covers standard, oversize and 2-1 piston rods, giving full information on all sizes from 1½" to 8" bores.

SPECIAL FEATURES

Included are detailed explanations of the many features which have made ORTMAN-MILLER cylinders standard in thousands of plants throughout the country. Detailed drawings and copy explain the special shear bar assembly which completely eliminates bulky end caps and tie rods, thus saving up to ⅓ in space. In addition, it shows the vast number of interchangeable mountings and applications which almost always eliminate the need for special castings or patterns. This feature alone not only saves initial costs, but cuts down on inventory and greatly speeds up delivery on every order.

Special Note:

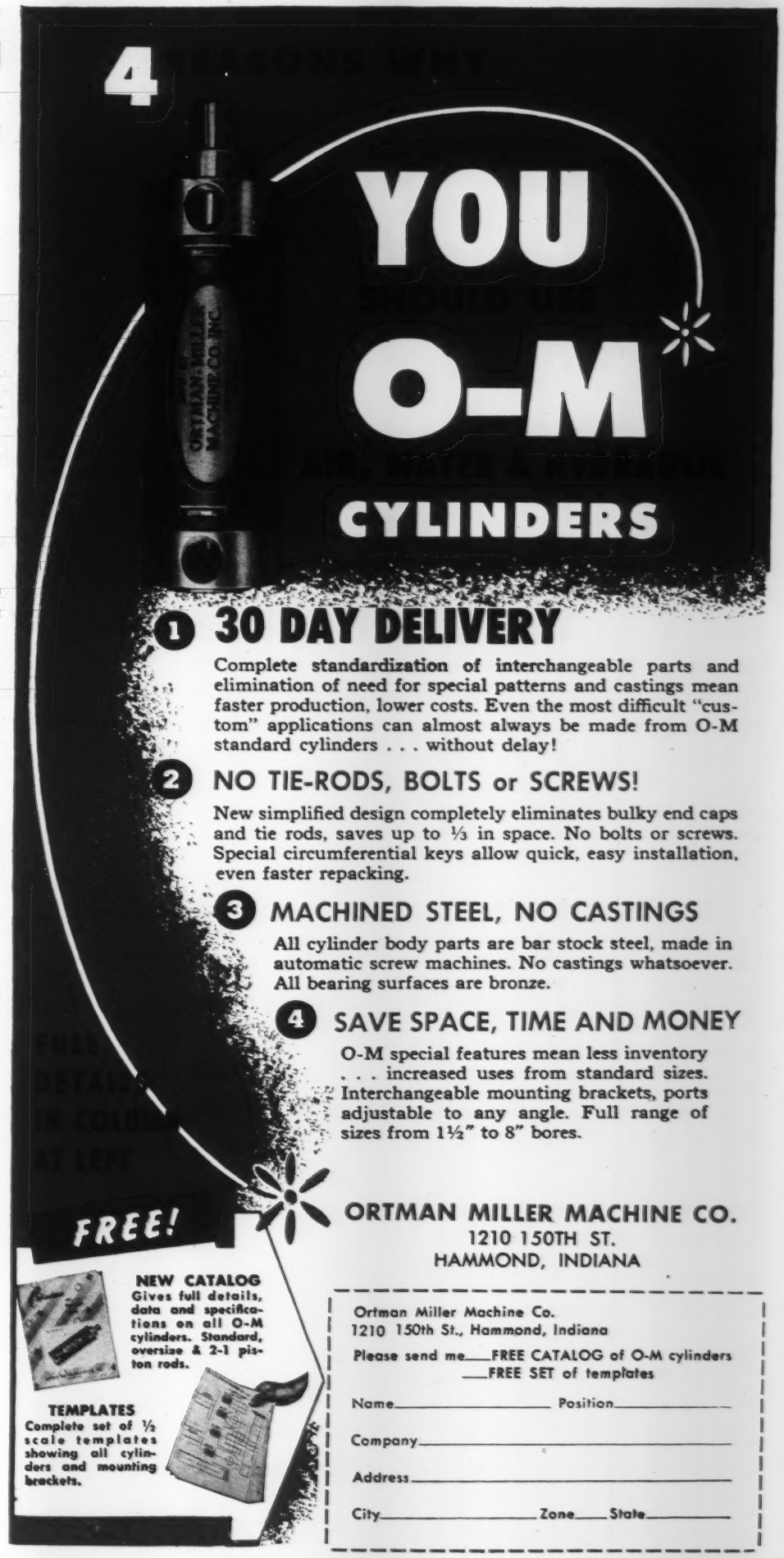
30 DAY DELIVERY

Increased production facilities and standardization of parts continue to make possible delivery in 30 days or less on almost all orders for O-M cylinders. Write today for details.

FREE TEMPLATES

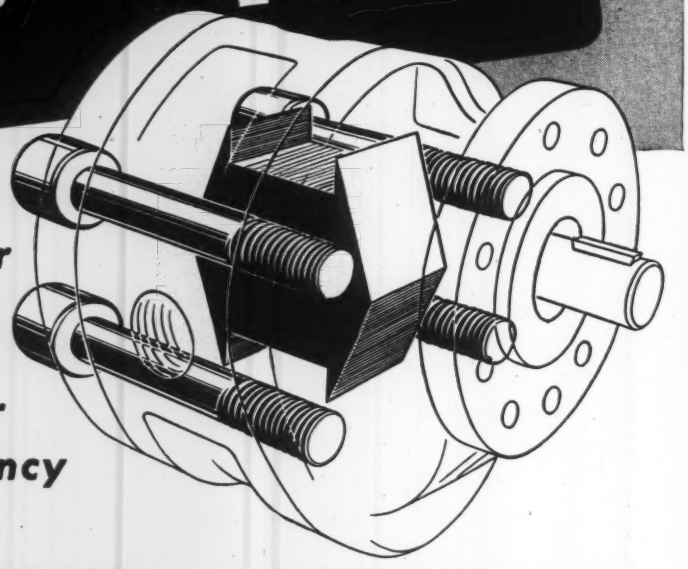
In addition to the FREE catalog, Ortman-Miller also leads the field in making available FREE TEMPLATES of all O-M cylinders. Prepared in half scale, they are extremely useful in design and application of O-M cylinders to your special requirements.

For your FREE Catalog or templates, use the coupon in the ad at the right. Or write to ORTMAN-MILLER Machine Co., 1210 150th St., Hammond, Indiana.



DO YOU USE *Oil Hydraulics?*

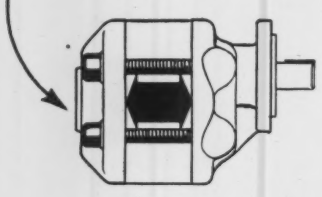
HYDRECO *Four Bolt* **PUMPS**



Give Longer Life With Higher Efficiency

For Hydraulic control systems of— Earth Moving—Road Building— Materials Handling Equipment

HYDRECO FOUR-BOLT DESIGN . . . locates the assembly bolts close within the area of greatest internal pressure — insuring **rigidity and stability** in design that cannot be equalled. Closer internal clearances are permanently built into the pump. There are no complicated internal mechanisms to "foul-up" from dirty oil.



Write for Catalog and Full Information

HYDRAULIC EQUIPMENT COMPANY

1106 EAST 222nd STREET • CLEVELAND 17, OHIO

SALES Notes

MANUFACTURER and fabricator of laminated plastics for industry, **Synthane Corp.**, Oaks, Pa., has established a new sales office at 54 West 30th St., Indianapolis 8, Ind. Duane W. Roland, a member of the company's New York sales staff for the past three years, is district representative in charge of the new office, which serves southern Indiana, southwest Ohio, and Kentucky.

♦

District sales offices of the **Reliance Electric & Engineering Co.** in Detroit and Cleveland have been moved to larger quarters. Facilities of the Detroit office, now located at 12326 Hamilton Ave., include warehousing space for stocking a complete line of ac motors of the open and totally - enclosed types. The company subsequently plans to stock its packaged adjustable-speed drives and renewal motor parts at this new location, also. The new location of the Cleveland office is 13967 Cedar Rd., Cleveland 18, O.

♦

Appointment of the **Shawray Plastics Corp.**, 398 Broadway, New York, N. Y., as a convertor-distributor of Vinylfilm has been announced by **Goodyear Tire & Rubber Co.**, Akron.

♦

Allis-Chalmers Mfg. Co., Milwaukee, recently appointed **Electrical Equipment Co. Inc.**, Davenport, Iowa, as a dealer for motors, control equipment, pumps and transformers in eight eastern Iowa counties and in five counties in northwest and western Illinois. At the same time, **Utility Transformer & Equipment Co.** was named a certified service shop for Allis-Chalmers transformers in nine northern and western Wisconsin counties and in seven counties in the upper peninsula of Michigan. The company has also appointed **S. H. Byers Equipment Co.**, New Castle,

SILICONE "O" RINGS

Good News For Today's Designer

Results from a recent survey show the successful use of a variety of silicone compounds in seal applications never attempted before with a resilient material because of temperature limitations. According to Linear, Incorporated, of Philadelphia, Pa., a principal manufacturer of "O" Rings, one group of silicone compounds have been designed for general use at temperatures ranging from −65° to +500°F. Modifications of the general purpose stocks have produced several compounds with extreme low temperature flexibility. Other types possess a maximum resistance to compression set over a wide temperature range.

Chart Tells The Story

SILICONE RUBBER STOCKS

Linear Style No.	Hardness Shore A Scale	Tensile Strength Min. (P.S.I.)	Elongation Min. (%)	Temp. Range (°F.)	Compression Set*	Color
ZK-50	50	400	100	−65 to +400	10 to 20	Red
ZA-60	60	400	150	−65 to +400	50 to 70	White
ZM-70	70	500	75	−65 to +400	15 to 25	Gray
ZN-80	80	600	50	−65 to +400	20 to 35	White
ZT-60	60	350	130	−125 to +400	30 to 50	Red
ZD-60	60	350	150	−85 to +400	40 to 60	Red
ZG-45	45	550	250	−125 to +400	40 to 60	Red-Tan
ZJ-60	60	500	70	−65 to +400	20 to 30	Red
ZP-80	80	550	50	−70 to +400	60 to 80	Gray
ZS-80	80	550	50	−70 to +400	25 to 30	Gray
ZU-50	50	600	225	−65 to +400	65 to 75	Neutral

* Method B 22 hours at 300°F

Notes:

1. *Temperature range values are based on actual experience in the field and the silicone rubber will perform very satisfactorily within these ranges over long periods of time. Intermittent temperatures as high as +500°F. are not harmful in most applications, but will shorten the ultimate life of the rubber.*
2. *All other values were determined at room temperature according to A.S.T.M. procedure. For silicones, room temperature values are retained with relatively little change over a wide temperature range. Therefore, they can be used with some assurance in selecting compounds for specific applications.*

Successful Usage Today

Silicone "O" Ring gaskets have proven to be highly successful as static sealing parts on a wide variety of equipment subject to extreme temperature conditions, oxidation, or to prolonged weathering. Silicone seals are giving outstanding service on certain types of aircraft shut-off valves which control the in-take of hot air from the intermediate stages of jet engine compressors under 500°F. operating conditions. Further investigation indicates the use of silicone "O" Rings on outdoor flood-lights, steam irons, transformers, geophysical equipment and diesel engines.

Research For Tomorrow

Linear Incorporated is continuing its Research Program to develop new silicone seals to meet the increasing demand for elastomers having a wide variety of physical properties. The future indicates that there will be expanding requirements for the many advantages offered by silicone as an outstanding engineering material for sealing purposes.

Advertisement

GASKET SPECIFICATIONS:

- MUST WITHSTAND TEMPERATURE VARIATIONS OF —125°F. to +400°F.
- MUST BE MOISTURE RESISTANT
- MUST WITHSTAND SEVERE THERMAL AND MECHANICAL SHOCK

LINEAR

SILICONE "O" RING GASKETS MEET TOUGH SPECIFICATIONS

LINEAR Silicone "O" Rings help the design engineer solve any number of unusual specifications. The ability to withstand extremes in temperature, for example, is typical of the high flexibility of this seal.

In this application, the need was for a gasket with a flexibility that could resist heat as high as +400°F. or cold as low as —125°F. Complete elimination of moisture, oxidation, thermal and mechanical shock to lens and bulb of the searchlight was an absolute must.

The sales potential of this product has been strengthened with LINEAR Silicone "O" Ring Gaskets. No longer do gaskets deteriorate rapidly, permitting moisture to enter socket . . . no longer do bulbs break because of thermal or mechanical shock . . . no longer is it necessary to replace gaskets whenever a bulb needs replacing. LINEAR "O" Rings keep a tight, moisture-proof seal throughout all extremes of weathering—they do not become gummy or stick at high temperatures.

To lower costs and reduce sealing maintenance, consult LINEAR for all your sealing requirements.

"PERFECTLY ENGINEERED PACKINGS"

LINEAR

LINEAR, Inc., STATE ROAD & LEVICK STREET, PHILADELPHIA 35, PA.

Product of
Westinghouse
Electric Corp.
Beaver,
Pennsylvania

The Westinghouse "F" Frame Circuit Breaker is a 3-pole type so designed that when a fault occurs on any one of the three lines, *all three* contacts open and current flow stops. The Trip Bar is made common to all three lines, and each line is protected by a complete set of circuit breaker components, including a magnetic trip element and a Chace Thermostatic Bimetal trip element. One of the desirable features of this protective device is the exclusive "DE-ION" Arc Quencher for fast, sure circuit arc extinction.

The versatile Chace Bimetal action is best suited to temporary overloads—with relatively long delay on light overloads and short delay on heavy overloads. When a sustained overload is on the circuit the current heats the Bimetal Trip Element (A) causing it to flex toward the low responsive side in the direction of the load terminal. The Latch (B) slides off the Transfer Arm (C) which pivots under pressure of its spring, pressing down the Trip Bar (D), causing it to rotate and release the Trip Actuating Arm (E). This allows the Trip Toggle Mechanism (F) to operate and open the contacts. Arc interruption is aided here by "DE-ION" Arc Chutes (G). The magnetic action (H) causes "snap-action" and the instantaneous breaking of short-circuit currents.

If the actuating element for your new control device is thermostatic bimetal, Chace is equipped and qualified to fabricate it ready for assembly. Our 29 types are also available in strips, coils, random long lengths and welded or brazed sub-assemblies. We invite you to consult with our application engineers—recognized authorities on temperature responsive devices. Write for our 64-page reference on the selection and design of thermostatic bimetal elements.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1616 BEARD AVE., DETROIT 9, MICH.

Pa., as distributor for motors, controls, pumps, transformers and Texrope drive equipment in seven counties of northwestern Pennsylvania. **Roach Equipment Mfg. Co.**, Tulsa, Okla., is a new distributor for motors and transformers in Tulsa, Washington, Kay, Seminole and Creek counties.

◆

In order to expand service to customers in the Pittsburgh area, **Pratt & Whitney Div., Niles-Bement-Pond Co.**, West Hartford, Conn., has relocated its Pittsburgh office. A new building at 683 Lincoln Ave. provides additional space for stocking precision cutting tools and gages and accommodates sales and service personnel associated with the line of machine tools, cutting tools and gages produced by Pratt & Whitney and its subsidiary, **Potter & Johnston Co.** of Pawtucket, R. I.

◆

Establishment of a second special district sales office for the Fiber Glass division of **Libbey-Owens-Ford Glass Co.**, Toledo, O., has been announced. The new office, under the direction of Mark Joseph Wells, will be located at 120 South La Salle St., Chicago, Ill.

◆

Hammel - Dahl Co., Providence, R. I., manufacturer of automatic control equipment, has announced the appointment of **Cowles & Co.**, Dallas, Tex., as sales and service representative in the central Texas area.

◆

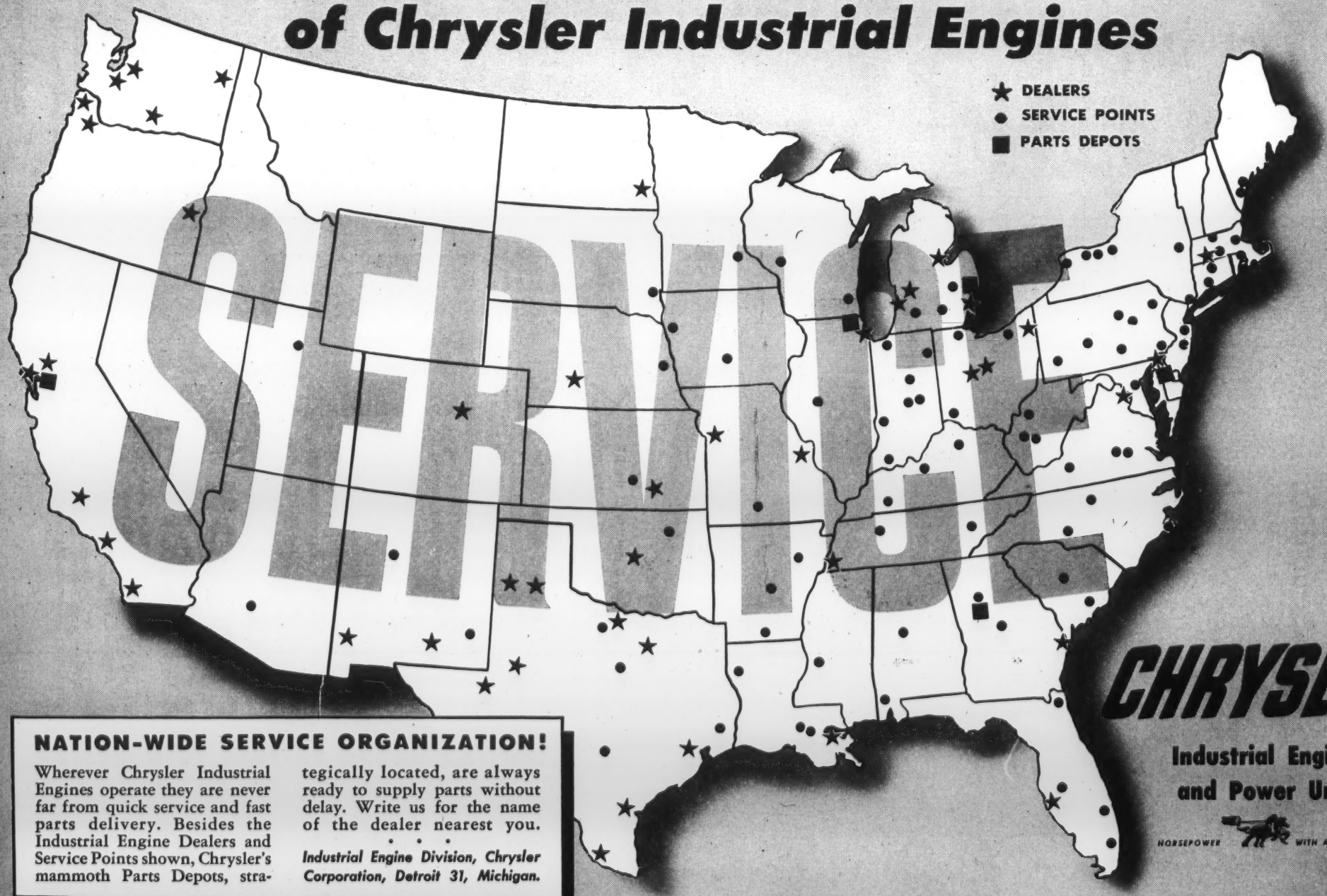
To provide better service and deliveries to the St. Louis industrial area, **Quaker Rubber Corp.**, division of **H. K. Porter Co. Inc.**, Philadelphia, has established a stock-carrying branch warehouse and sales office at 4006 Papin St., St. Louis, Mo. The new branch will operate under the supervision of J. H. Joyner, district sales manager.

◆

Selas Corp. of America, Philadelphia, has announced the opening of a Pittsburgh office at 3829 Willow Ave., under the direction of John L. Wilson, who has represented Selas in the Pittsburgh area for three years.

THE GREAT INVISIBLE FEATURE

of Chrysler Industrial Engines



NATION-WIDE SERVICE ORGANIZATION!

Wherever Chrysler Industrial Engines operate they are never far from quick service and fast parts delivery. Besides the Industrial Engine Dealers and Service Points shown, Chrysler's mammoth Parts Depots, strategically located, are always ready to supply parts without delay. Write us for the name of the dealer nearest you.

• • •

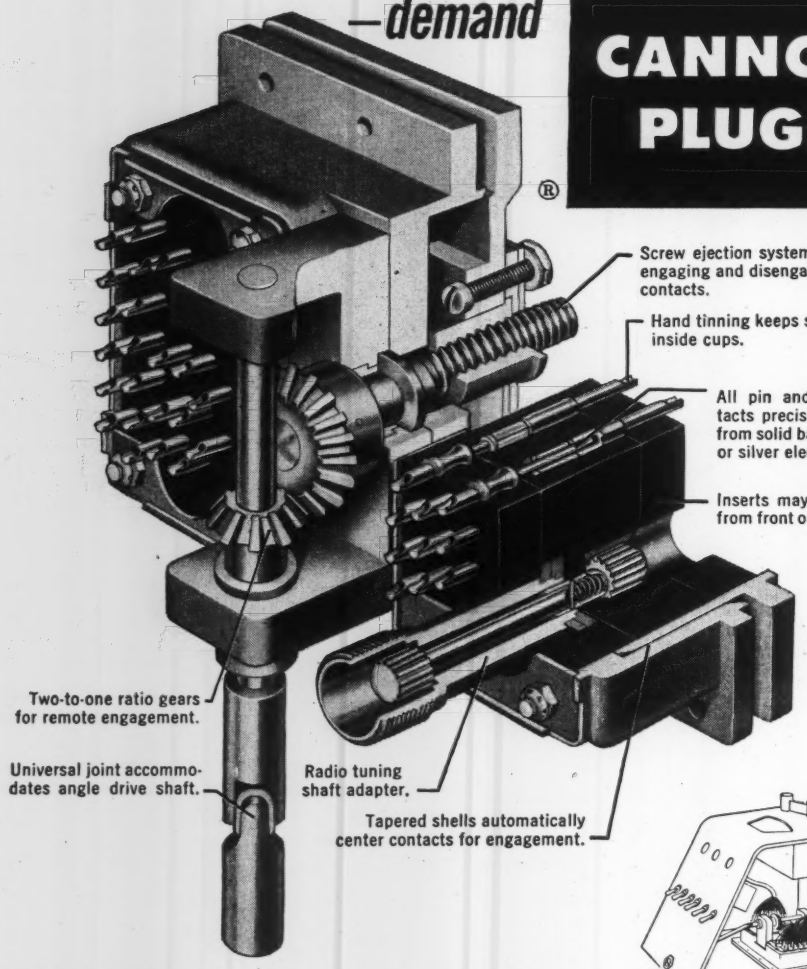
Industrial Engine Division, Chrysler Corporation, Detroit 31, Michigan.

CHRYSLER

Industrial Engines and Power Units

HORSEPOWER WITH A PEDIGREE

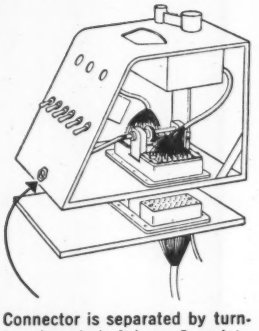
Here's why those in the know —demand CANNON PLUGS®



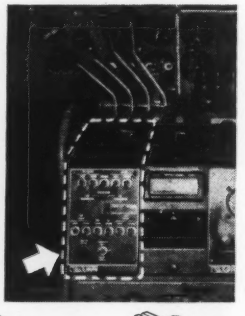
This highly specialized DPD2 Cannon Plug, a member of the DP Series, has its principal use in aircraft instrument panels and remote radio control equipment. But, like many other Cannon Plugs, it has found its way into other fields where the highest quality is needed and where the value of long, trouble-free performance is recognized.

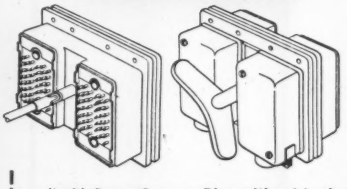
Originally this 2-gang connector was designed to assist in the standardization of radio and instrument assemblies so that such equipment might be interchanged between similar aircraft. It allows for compact design in close quarters with access from the front only. This type of application and variations of the fittings are shown at right. Any Cannon DPD insert may be placed within the shell, with or without tuning shaft, coax, twinax, large or small contacts, provided the separation forces of both halves are similar.

This plug typifies the close attention to important detail that distinguishes every Cannon Plug—the world's most extensive line. If you are looking for real value, regardless of the field you work in, your best bet is Cannon.



Connector is separated by turning slotted shaft here. Complete unit may then be removed from pedestal, shown below.





(Left) Same Cannon Plug without tuning shaft. Straight drive instead of 90° gear. (Right) Similar DPD2 with Dzus wing nut extraction method and junction shells. There are several other variations. Write for details.

CANNON ELECTRIC

Since 1915

CANNON ELECTRIC COMPANY
LOS ANGELES 31, CALIFORNIA

Factories in Los Angeles, Toronto, New Haven. Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. D185, P. O. Box 75, Lincoln Heights Station, Los Angeles 31, California.

Meetings

AND EXPOSITIONS

Apr. 16-18—

American Institute of Electrical Engineers. Third conference on electric welding to be held at the Rackham Memorial Building, Detroit, Mich. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

Apr. 21-24—

Society of Automotive Engineers. Aeronautic, aircraft engineering display and technical air review to be held at the Statler Hotel, New York, N. Y. John A. C. Warner, 29 West 39th St., New York 18, N. Y., is secretary and general manager.

Apr. 27-May 1—

American Ceramic Society. The 54th annual meeting to be held at the William Penn Hotel, Pittsburgh, Pa. Additional information may be obtained from society headquarters, 2525 North High St., Columbus 2, O.

Apr. 29-30—

Metal Powder Association. Eighth annual meeting and exhibit to be held at the Drake Hotel, Chicago, Ill. Additional information may be obtained from association headquarters, 420 Lexington Ave., New York 17, N. Y.

Apr. 30-May 2—

American Institute of Electrical Engineers. Northeastern district meeting to be held at the Arlington Hotel, Binghamton, N. Y. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

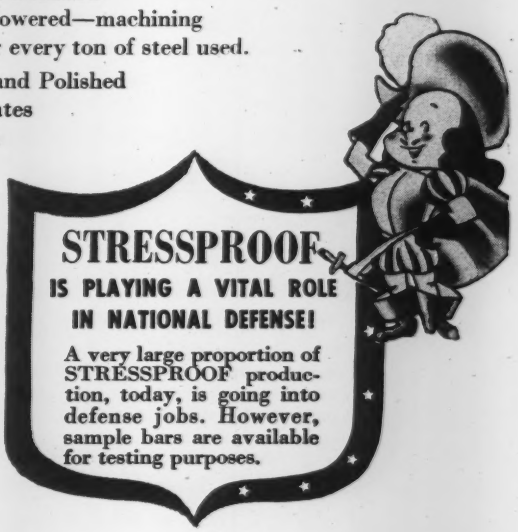
May 1-2

Society of Naval Architects and Marine Engineers. Annual spring meeting to be held at the Roosevelt Hotel, New Orleans, La. Additional information may be obtained from society headquarters,

GROUND and POLISHED STRESSPROOF®

The cable drum shaft of this Army truck winch was formerly made from 4140 alloy steel—cold-drawn, heat-treated, stress-relieved, ground, and polished. It was difficult to machine, and expensive. Several years ago this alloy bar was replaced with Ground and Polished STRESSPROOF at a considerable saving. Steel costs were *substantially* lowered—machining time was reduced. As a result, the over-all savings amounted to $50.00 for every ton of steel used.

This is typical of the sensational savings made possible with Ground and Polished STRESSPROOF—the finest ground bar steel produced. This bar eliminates many costly manufacturing operations because of its unique combination of five important qualities in the bar: High Strength... Excellent Wearability... Minimum Warpage... Accurate, Polished Surface... and Machinability fully 50% faster than heat-treated alloys of the same hardness!

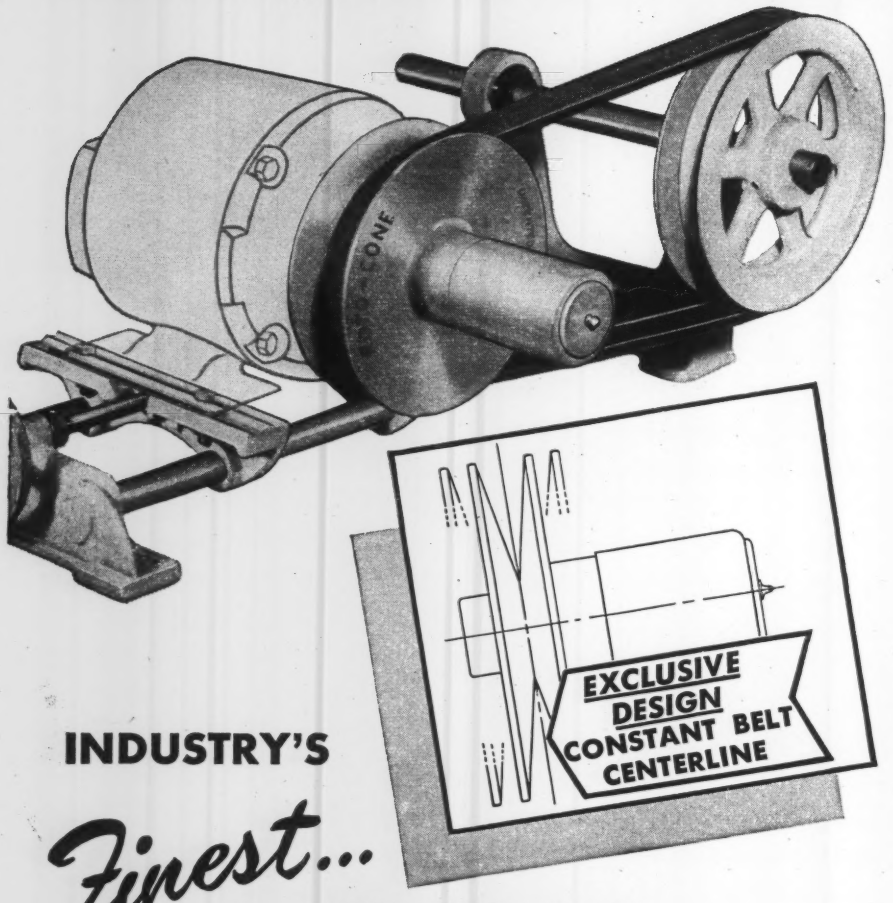


La Salle STEEL CO.

1426 150th STREET, HAMMOND, INDIANA

Manufacturers of the Most Complete Line of Cold-Finished and Ground and Polished Bars in America

ROTO-CONE
VARIABLE SPEED DEVICES



INDUSTRY'S

Finest...

YET MOST ECONOMICAL

VARIABLE SPEED PULLEYS AND DRIVES

Smooth, infinitely variable speed can be yours with Roto-Cone, industry's finest, yet most economical V to V variable speed drives. Positive rack and pinion arrangement, *exclusive* in Roto-Cone variable speed motor pulley, provides equal and opposite lateral movement of both discs, therefore, V-belt always travels on a fixed center line. Pulleys are dynamically and statically balanced and do not have interlocking sheaves. Result is maximum vibrationless transmission of power and full belt life.

The Roto-Cone line is complete . . . variable speed pulleys, adjustable motor bases, V-belts, and V-driven sheaves . . . All tested and proven on thousands of actual installations.

Yes . . . you can easily add productivity or saleability to your present drive with Roto-Cone. Up to 4 to 1 speed-change ratios are available. Wide selection of sizes from ⅛ to 15 H.P. Write for details and request the assistance of our speed control engineers.

ROTO-CONE

Complete VARIABLE SPEED DRIVES

GERBING MANUFACTURING CORP.

NORTHBROOK, ILL. (A Suburb of Chicago) Dept. C-RC

29 West 39th St., New York 18, N. Y.

May 1-7—

American Foundrymen's Society. 56th annual meeting to be held at Convention Hall, Atlantic City, N. J. Additional information may be obtained from society headquarters, 616 South Michigan Ave., Chicago 5, Ill.

May 5-16—

British Industries Fair to be held at Olympia and Earl's Court, London, and at Castle Bromwich, Birmingham, England. Additional information may be obtained from British Information Services, 30 Rockefeller Plaza, New York 20, N. Y.

May 6-9—

Scientific Apparatus Makers Association. 34th annual meeting to be held at Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 20 North Wacker Drive, Chicago 6, Ill.

May 14-16—

Society for Experimental Stress Analysis. Spring meeting to be held at the Hotel Lincoln, Indianapolis, Ind. Additional information may be obtained from society headquarters, P. O. Box 168, Cambridge 39, Mass.

May 17-June 2—

Paris Fair to be held at the Port de Versailles, Paris, France. Additional information may be obtained from Rowland Associates, 420 Lexington Ave., New York 17, N. Y.

May 22-24—

American Society for Quality Control. Sixth annual convention to be held at Onondaga County War Memorial Auditorium, Syracuse, N. Y. Additional information may be obtained from society headquarters, 70 East 45th St., New York 17, N. Y.

June 4-10—

International Mechanical Engineering Congress. Fourth congress to be held at the Gillet Hotel, Brunkebergstorg, Stockholm. C. de Novar, 10 Avenue Hoche, Paris 8, France is permanent secretary.

Speed Nut
SAVINGS STORIES

Saving Weight

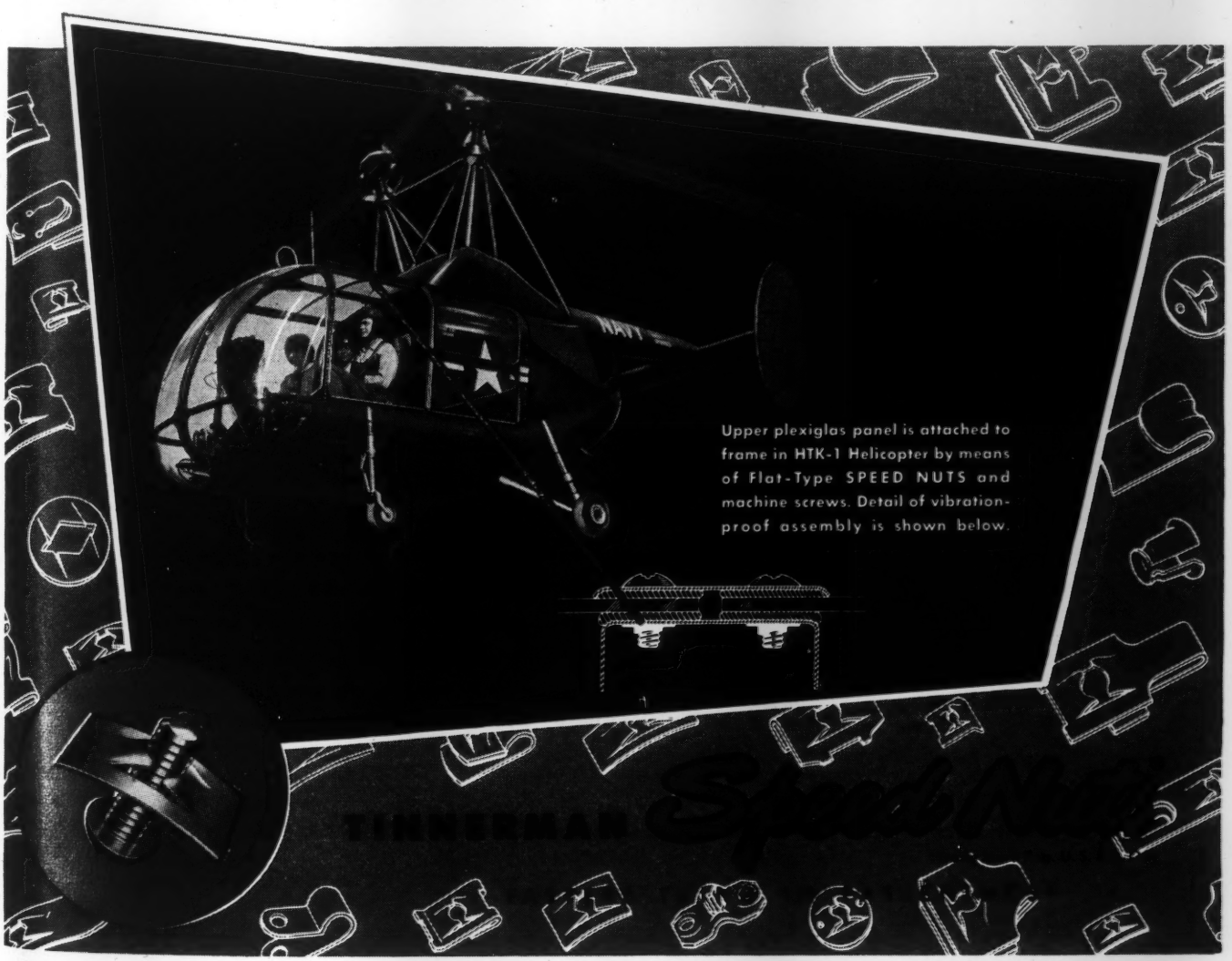
TO SAVE MORE LIVES

How SPEED NUTS made important weight savings attaching plexiglas panels in Kaman Helicopter.

Let the engineers at Kaman Aircraft Corp., Windsor Locks, Conn., tell you how Flat-Type SPEED NUTS performed for them. "We found that lightweight SPEED NUTS provide a large bearing surface which eliminates the need for flat washers under nut. *They reduce the weight up to .31 pounds per hundred when replacing other lock nuts, not including savings on weight of washers.*

"Only one part to handle in assembly means faster, easier attachments. SPEED NUTS are retained in screw-receiving position by finger-tip pressure—no wrench needed to pull down NUTS. *These advantages add up to savings of approximately .15 man-hours per hundred fasteners.*"

If you would like to hear similar savings reports from *your* engineers, specify SPEED NUTS. Your Tinnerman representative can help you determine the right fastener for the job. Call him in soon. And write for your copy of "Savings Stories" Vol. II, Tinnerman Products, Inc., Dept. 12, Box 6688, Cleveland 1, Ohio. *In Canada:* Dominion Fasteners Ltd., Hamilton. *In Great Britain:* Simmonds Aerocessories, Ltd., Treforest, Wales. *In France:* Aerocessoires Simmonds, S. A.—7 rue Henri Barbusse, Levallois (Seine) France.



Upper plexiglas panel is attached to frame in HTK-1 Helicopter by means of Flat-Type SPEED NUTS and machine screws. Detail of vibration-proof assembly is shown below.

You'll find American STOCK Gears meet every requirement for high quality, accurate tooth contour, smooth, quiet performance and long life.

Complete line includes Spur Gears . . Racks . . Change Gears . . Internal Gears . . Miter Gears . . Bevel Gears . . Ratchets and Pawls . . Spiral Gears . . Worms and Worm Wheels.

Order from the nearest of these authorized distributors

ALABAMA
BIRMINGHAM
Industrial Supplies, Inc., 613 North 9th St.
CALIFORNIA
LOS ANGELES
Marwood Ltd., 320 E. Third Street
SAN FRANCISCO
Marwood Ltd., 357 Ninth Street
CONNECTICUT
BRIDGEPORT
H. J. Behn & Co., Inc., P.O. Box 1780
ATERBURY
WCharles A. Templeton, Inc.
GEORGIA
ATLANTA
Industrial Service Company
P. O. Box 128, Station E.
ILLINOIS
CHICAGO
Chain Sales, Inc., 640 West Washington Blvd.
Dodge-Chicago Industrial Eq. Co.
2450 So. Wabash Ave.
Patlyn Gears & Trans. Co., 2456 W. 38th Street
ROCKFORD
Rockford Tool & Transmission Co., 802 Broadway
INDIANA
INDIANAPOLIS
Indianapolis Belting & Supply Co.
30-36 So. Capitol Avenue
SOUTH BEND
Central Equip. Co., 921 South Main St.
IOWA
DAVENPORT
Industrial Engineering Eq. Co.
122-124 East Fourth Street
KENTUCKY
LOUISVILLE
Bearings, Inc., 501 W. Main Street
LOUISIANA
NEW ORLEANS
Industrial Power Trans. Co.
1117 La Salle St.
MASSACHUSETTS
BOSTON
Park Gear & Machine Inc.
3368 Washington Street
SPRINGFIELD
Stacy Supply Co., 43 Taylor Street
MICHIGAN
DETROIT
DuComb Company W. C., 6335 East Palmer Ave.
GRAND RAPIDS
State Supply Company, 751 Grandville Ave. S. W.
KALAMAZOO
Robert M. Sorlie Co., 419 East Dutton St.
SAGINAW
B-H Supply Co., 405 Ames St.
MINNESOTA
MINNEAPOLIS
Baldwin Supply Co., 1329 South Sixth Street
MISSOURI
KANSAS CITY
Nooiling Steel Sales Corp., 1517 Cherry Street
ST. LOUIS
Ta-Co., Inc., 801 No. Second Street
NEW JERSEY
NEWARK
Dodge Newark Supply Co., Inc.
281 Market Street
TRENTON
Wiley-Hughes Supply Co., Inc.
Spruce St. Corner New York Ave.
NEW YORK
BROOKLYN
Acme Leather Belting Co., 578 Broadway
Petty & Wherry, Inc., 333 Atlantic Avenue
BUFFALO
Buffalo Rubber & Supply Inc., 37 Carroll St
JAMAICA
Industrial Bearing & Supply of L. I.
91-12 143rd Street
LOCKPORT
Ward Bros. Mill Supply Co., 64 Market Street
LONG ISLAND CITY
Beardslee Transmission Equipment Co.
41-12 29th Street Bridge Plaza North
NEW YORK
Congro Transmission Co., 388 Broome Street
Fisher Tool Co., 226 La Fayette Street
TROY
Troy Belting & Supply Co.
6-8 Grand St.
UTICA
Millar & Sons Co., Charles
NORTH CAROLINA
CHARLOTTE
Precision Gear & Mach. Co., Inc.
2001 N. Tryon St.
OHIO
AKRON
Mahoning Valley Supply Co.
1001 South High St.
CANTON
Mahoning Valley Supply Co.
1253 Dueber Ave., S. W.
CLEVELAND
J. A. Shomer, 11201 Berea Rd.
CINCINNATI
Wirthlin-Mann Co., 1930 Dana Ave.
DAYTON
Dills Supply Co., 200 Wayne Avenue
TOLEDO
G & J Supply Co., 615 Phillips Ave.
YOUNGSTOWN
Mahoning Valley Supply Co.
704 Youngstown-Poland Road
OKLAHOMA
TULSA
Weiss Supply Company
216 East Third St.
OREGON
PORTLAND
Marwood Ltd.
209 S.W. First Ave.
PENNSYLVANIA
PITTSBURGH
Harris Pump & Supply Co.
Brady & Sidney Sts., S. S.
TENNESSEE
MEMPHIS
The Rischman Crosby Co., 223-29 So. Front St.
NASHVILLE
Tenn. Machinery Co., 113 3rd Ave. S.
TEXAS
DALLAS
Bearing, Chain & Supply Co.
2826 Elm St.
HOUSTON
American Gear & Supply Co., 3438 Leeland Ave.
VIRGINIA
RICHMOND
Apex Machine Mfg. Co., 216 So. Fifth Street
WASHINGTON
SEATTLE
Marwood Limited, 1714 First Avenue South
WISCONSIN
GREEN BAY
Libert Bearing Co., 324 No. Roosevelt St.
MADISON
Richard E. Ela Co.
744 Williamson St.
MILWAUKEE
American Machinery Co., 453 No. Plankinton

Write us for a free copy of Specification Catalog

asg **AMERICAN STOCK GEAR** division
PERFECTION GEAR COMPANY • HARVEY, ILLINOIS

New Machines

Domestic

Electric Sink: Has front-opening, top-loading automatic dishwasher under porcelain enameled sink and drainboard. Dishwasher washes and dries up to 100 pieces of china, glassware, etc., in 30 min. Size: 48 in. wide, 25 in. deep, 36 in. high. *Major Appliance Div., General Electric Co., Louisville, Ky.*

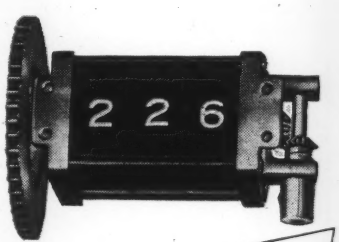
Automatic Washer: Tumble action model features heater for wash water. Dial on top of washer has two positions—hot for washing cycle, and warm for rinsing. Heater operates on 110 volts, using 1200 watts. *Bendix Home Appliances Div., Avco Mfg. Corp., South Bend, Ind.*

Heating and Ventilating

Panel Heater: Employs new electric heat process that eliminates hot wire elements. Attains a uniform temperature of approximately 190 F over entire surface. Can be hung flush against wall or suspended from ceiling. Operates on 110-v current; dual voltage heaters using either 110 or 220 volts are also available. Size: 2 by 3 ft. *Electrofilm Corp., North Hollywood, Calif.*

Circulator-Window Fan: Portable model may be used to pull in fresh air or exhaust stale air, or as circulating fan. Adjustable in height from 28 to 48 in., floor to center of blades. Vertical tilt adjustment permits air flow to be directed within an arc of 180 deg. Has quiet overlapping type blades and two-speed capacitor motor. Delivers 3750 cu ft of air per minute at high speed. *The Emerson Electric Mfg. Co., St. Louis, Mo.*

Cabinet Unit Heaters: Three new models for heating lobbies, entrances, showrooms, etc. Include a freestanding unit, a semi-recessed design and a completely recessed cabinet. All have front inlet and outlet grilles designed for blanketing doorways or other areas where air must be discharged horizontally



Small Component... or Complete Unit... You* can count on getting whatever You* need—

Added Evidence that—

Everyone Can Count on VEEDER-ROOT

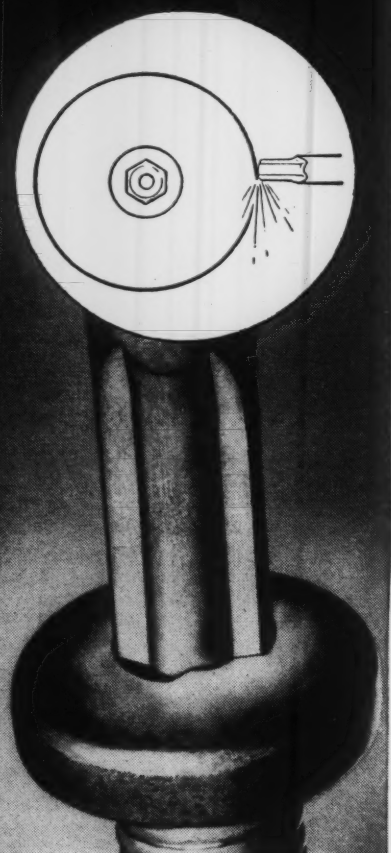
This REEL CONTROL BOX, complete with its *built-in* counting mechanism, indicates the number of feet of antenna reeled in and out of certain types of military aircraft. Manufactured completely by Veeder-Root, including outside bakelite cover and box, this unit shows another imaginative application of the universal language of direct-reading *Count*rol.

Now if you, *in any of your defense work,** have a counting problem, then you can count on Veeder-Root to help you in every possible way.

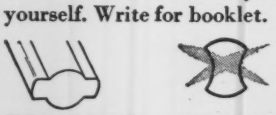
VEEDER-ROOT INCORPORATED
"The Name That Counts"
HARTFORD 2, CONN. • GREENVILLE, S.C.
Montreal 2, Canada • Dundee, Scotland
Offices and agents in principal cities

"Counts Everything on Earth"

UNITED
CLUTCH HEAD®
SCREWS



Another advantage to Clutch Head screw users. There is no need to throw away your driver because it is worn. Just grind back the point of the Type A bit and in a few seconds you have a new bit ready to drive thousands of more screws. Try it yourself. Write for booklet.



TYPE "A" BIT NOT THIS

®Reg. U.S. Pat. Off.

UNITED SCREW and BOLT CORP.
CHICAGO 8, ILL. • CLEVELAND 2, OHIO
NEW YORK 7, N.Y.

from unit. Can be installed in either steam or hot water systems, with capacities up to 105,000 Btu. *The Trane Co., La Crosse, Wis.*

Reversible Window Fan: Sixteen-inch unit. Switch controls direction of rotation. Has two-speed capacitor motor and balanced overlapping type blades. Panels adjust for installation in windows 29⅛ to 36 in. wide; mounting chains supplied for installation in smaller windows. Delivers 2000 cfm. *The Emerson Electric Mfg. Co., St. Louis, Mo.*

Air Conditioners: Window sill type units have hermetically sealed refrigeration circuit. Model 4, ⅓-hp unit, protrudes 10 in. into room; can be installed in almost any type window. Has four-way adjustable air distribution grilles and heavy-duty disposable type filters which can be reached without removing cabinet from its mountings. Model 51, one-hp unit for large rooms, features draft-free circulation accomplished by means of adjustable rotary grilles. *York Corp., York, Pa.*

Materials Handling

Lift Trucks: Four models will lift 800-lb loads to heights of 52, 66 and 78 in.; 52-in. size available in both foot-operated and electric-hydraulic operation. Equipped with heavy-duty recharging plant. Feature dual ball and roller bearings throughout. *Big Joe Mfg. Co., Chicago, Ill.*

Conveyor: Heavy-duty unit, 12 in. wide, is made in 5 and 10-ft sections with 45 and 90-deg curves to suit special and individual needs. Ball-bearing wheels 2 in. in diameter and ⅝ in. wide are spaced on slightly less than 3-in. centers. Available with welded-on connectors which are interconnectable with most wheel conveyors of the same size. Rated to take loads of 1000 lb covering the surface of the conveyor and for individual loads up to 300 lb. Side channel members are joined by inverted angles welded to both side channels. *Market Forge Co., Materials Handling Div., Everett, Mass.*

Table Type Belt Conveyor: Belt available in any length or width; can be made of white neoprene, stitched or woven canvas, or rubber. A 15-in. maple, masonite, or

CONTROLLED
TIMER
at a price you can afford

PRE-SET, TAMPER-PROOF TIMING

Practically non-breakable, Durakool Pre-set Timer Relays have more than proved themselves on the roughest and toughest jobs that could be found. Year by year, their use increases in sensational fashion. Controlled time available from .15 to 20.0 seconds in either normally open or normally closed actions. 3 to 4 week delivery. No waiting. Your production schedule is met.

★ No false contacts
★ No chatter
★ Quiet in operation
★ Eliminates double contacting or breaking of circuit

See telephone directory for local distributor or write
DURAKOOL, INC., Elkhart, Ind.

Durakool
ALL-STEEL MERCURY
Timers

metal table is constructed on each side of traveling belt in work area. Height of legs is adjustable. Variable-speed drive runs belt at normal rate of 20 fpm; maximum speed is 40 fpm. *Flexoid Conveyor Co., Cleveland, O.*

Mobile Crane Trucks: Available in 6000 and 10,000-lb capacities. For handling heavy castings, machinery, bar stock, etc. Have 19-ft telescoping booms. *The Baker-Raulang Co., Baker Industrial Truck Div., Cleveland, O.*

Gravity Conveyor: Has special wheel arrangements and spacings to handle various types of merchandise. Tote box, trough, fence and laned conveyors available. *The Rapids-Standard Co. Inc., Grand Rapids, Mich.*

Electric Fork Truck: Capacity, 1500 lb. Has 59-in. turning radius; lifts at rate of 50 fpm loaded; hauls at rate of 6 mph. Has no grease points and no under-truck adjustments. Stand-up drive. *Lewis-Shepard Products Inc., Watertown, Mass.*

Metalworking

Piercing Units: Feature portability, high capacity, automatic hydraulic stripping. Model weighing 45 lb exerts force of 5 tons at 2000 psi working pressure. Maximum capacity is 12½ tons at 5000 psi working pressure. Also for use in riveting, trimming, bending or extruding. *Danly Machine Specialties Inc., Chicago, Ill.*

Feed Starter: For straightening and feeding the starting end of rod from coil. Operator positions coil up to unit, lets power feed roll take hold of starting end of rod, and rod is fed automatically through attached roll straightener. Feed rolls are backed off when straightened stock reaches pulling device on next machine. Two grooves on feed rolls accommodate wire up to ⅝-in. diameter; feed rolls also available for square stock. Controlled by switch mounted on right-hand side of unit. Rate of feed, 68 in. per minute. *Mettler Machine Tool Inc., New Haven, Conn.*

Three-Way Trunion Machine: Features extreme rigidity in central section and safety through automatic shut-off devices. Has two horizontal 30-in.-way hydraulic

TROSTEL

QUALITY

Engineered for your specific sealing requirements

There are no "standard" packings or oil seals in the complete Trostel line—only standard sizes. The seal itself . . . in leather or synthetic rubber . . . is individually developed for the requirements of each specific application . . . by one or more of three separate and distinct Trostel laboratories.

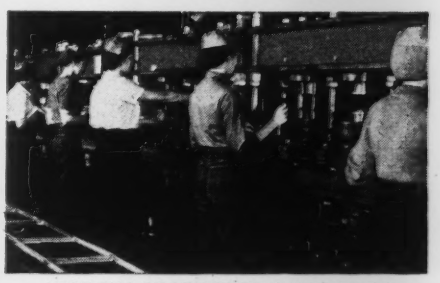
Working closely with the laboratories, the Trostel tool room designs and builds the tools which make it possible to retain *in production* the special properties and tolerances originated by the laboratories and pilot plant.

Modern production machinery... specially designed to permit *full automatic control* of critical time, pressure, and temperature cycles . . . provides further assurance of consistent quality.

We invite your inquiry.

LABORATORY CONTROL

COMPLETE TOOLING FACILITIES



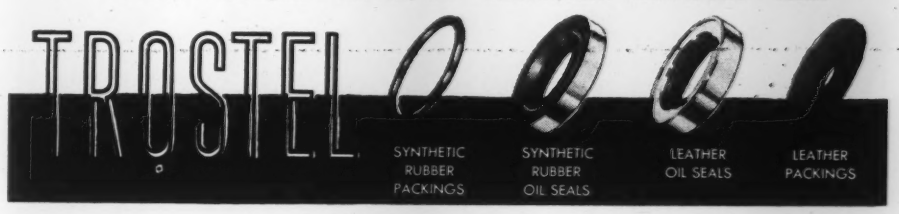
MODERN PRODUCTION MACHINERY

ALBERT TROSTEL & SONS COMPANY

General Offices and Packings Division • Milwaukee 1, Wis.

Sales Offices:

Houston • Los Angeles • New York, N. Y. • Worcester, Mass. • San Francisco • Seattle



ELECTRAN TRANSFORMERS

★ TRANSFORMERS
★ SATURABLE REACTORS
★ ELECTRONIC DEVICES

Specialists in SMALL quantities of custom built transformers from milliwatts to 50 KVA, single or polyphase— designed and manufactured to best meet your exact requirements.

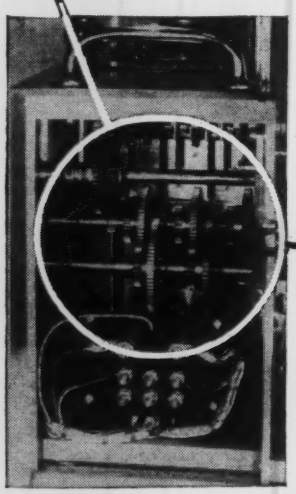
Each Electran Transformer is built to the highest standards of quality and precision. There is no "second" grade at Electran.

ELECTRAN MFG. CO.

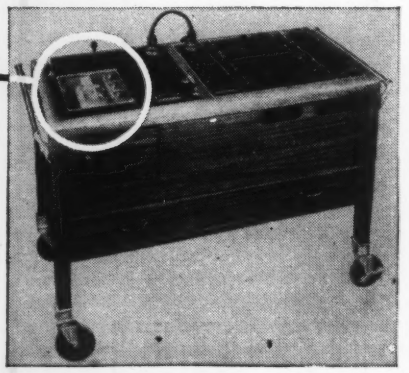
1901 CLYBOURN AVENUE • CHICAGO 14, ILLINOIS

Mass. G&T Gear

Applied in Biophysical Research Recorder



The Sanborn Company of Cambridge, Mass., manufacturer of the Poly-Viso Cardiette for biophysical research, is another of the many users of "Mass. Gears." This sensitive instrument calls for the application of gears of extreme precision, a requirement which is inherent in "Mass. Gear" production.



"Mass. Gear" is ready to assist you with your gear problems. Address: Massachusetts Gear & Tool Co., Woburn, Mass.

Massachusetts Gear & Tool Co.

Woburn, Mass.

units and one 8-in.-way hydraulic unit. Designed to process 880 valve rocker arms per hr at 100 per cent efficiency. Tooling includes six-station trunnion type fixture loading four parts to a station, with power indexing for the trunnion; a 20-spindle right-hand head, 12-spindle left-hand head and four-spindle rear head. Side heads are of cluster type construction. Weight of machine, 65,000 lb. *Buhr Machine Tool Co., Ann Arbor, Mich.*

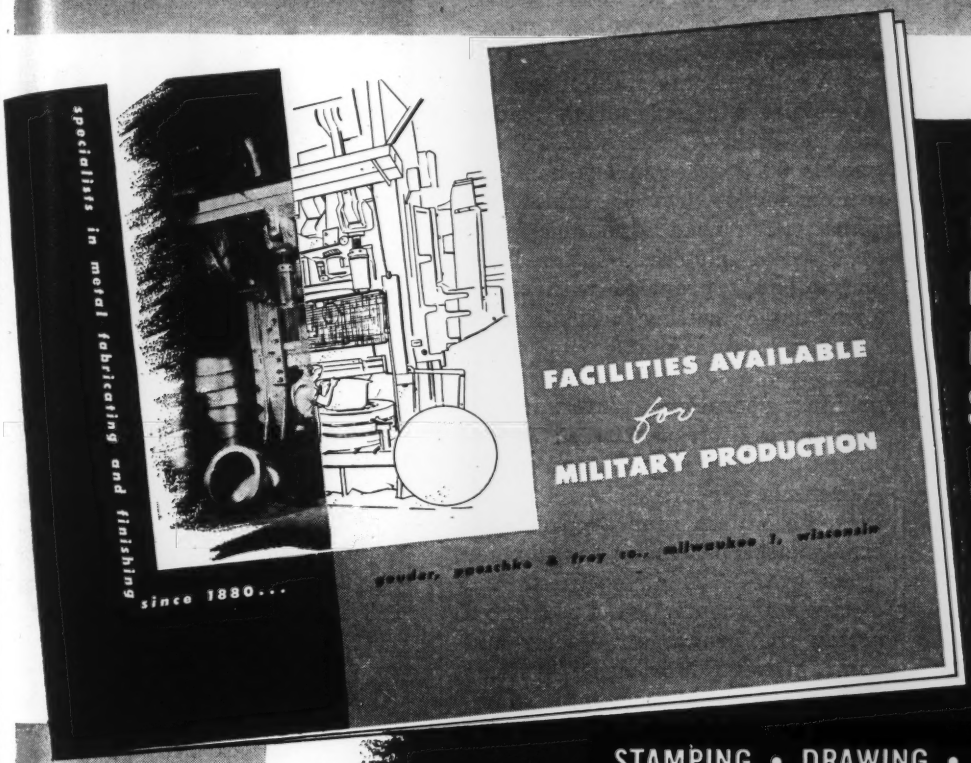
DC Arc Welders: Two models in 150 and 200-amp sizes. Excellent commutation claimed at all settings; self-exitation and split-pole, cross-field design provide good operation at all current settings. Continuous overlap from each current range to the next provides wide unbroken range of welding current—30 to 250 on 200-amp welder and 20-185 on 150-amp machine. Lightweight models are easily portable when mounted on two-wheeled carriage; require small amount of floor space. *Air Reduction Sales Co., Division of Air Reduction Co. Inc., New York, N. Y.*

Instrument Lathe: Model 608, an 8½-in. swing lathe turns or bores within 0.0001-in. in six-inch work held in collet or between centers. Backgeared, screwcutting engine lathe recommended for variety work. Attachments available for milling, spiral cutting, slotting, relieving, taper turning, radius turning, grinding and forming. Has three-point bed mounting; double-bevel alignment for head and tailstock; carriage bearing of 76 sq in. on bedways; separate lead screw for thread cutting; double taper, self-aligning spindle bearings; heat-treated precision ground feed screw. *Rivett Lathe & Grinder Inc., Boston, Mass.*

Milling Machine: A compact commutator undercutting unit, uses carbide tools for high-speed production applications. Has preloaded ball bearing table with tilt provisions for good visibility; hardened and ground elevating screw, ½-hp motor with V-belt drive. *Gay-Lee Co., Clawson, Mich.*

Cutter-Tool Grinder: Model 310, in 8 by 16-inch capacity, manufactured by Jones & Shipman of Leicester, England. Features include: self-contained motor drive with built-in switchgear; universal op-

NEED HELP ON YOUR MILITARY ORDERS?



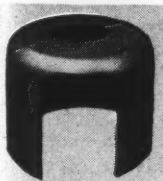
GET THIS BOOK OF FACTS ON OUR COMPLETE METAL FABRICATING FACILITIES FOR SUB-CONTRACT WORK

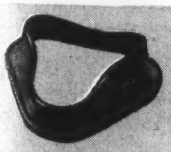
G.P.&F.
DEFENSE DIVISION
MILWAUKEE

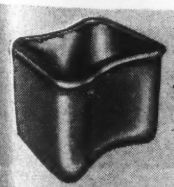
STAMPING • DRAWING • FORMING • TINNING
GALVANIZING • SPRAY FINISHING • WELDING
VITREOUS ENAMELING • LEAD COATING

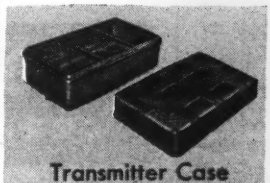
Typical Examples of Military Sub-contract Work

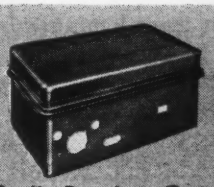
Electric Light Hood

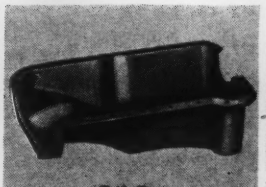

Motor Housing


Frame for Diving Helmet


Transmitter Case


Transmitter Case and Cover

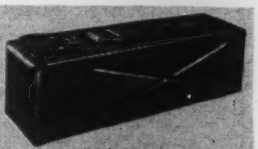

Radio Receiver Case


Oil Pan

Fuel Tank

Industrial Vacuum Cleaner Housing

Time Control Box


Aerial Delivery Container

● It's right off the press! Send for your FREE copy today! Gives details of this nationally-famous, 70-year-old company's technical efficiency, wide experience, modern facilities and ample capacity... to produce stampings of every description—whether simple or intricate in design. Whatever your metal fabricating problem may be... for military or civilian use... consult G. P. & F.

15 Acres of Production Facilities
Complete Machine Shop and Tool and Die Department

DEFENSE DIVISION
GEUDER, PAESCHKE & FREY CO.
1636 W. ST. PAUL AVE. • MILWAUKEE 1, WISCONSIN

LEBANON CIRCLE L
Castings
in Stainless and Special Alloys...
with Controlled High Quality

Lebanon Steel Foundry pattern makers study engineering designs, suggest improvements and plan jobs for production giving careful consideration to feed heads, rigging and gating. This care in preparation can save valuable time and eliminate costly failures. Pattern making, however, is but one of many steps in production rigidly followed by Lebanon craftsmen to provide CIRCLE Ⓛ castings of *controlled* high quality.

LEBANON STEEL FOUNDRY
Dept. G, Lebanon, Pennsylvania
"In the Lebanon Valley"

CIRCLE L **LEBANON** *Steel and Alloy Steel* Castings

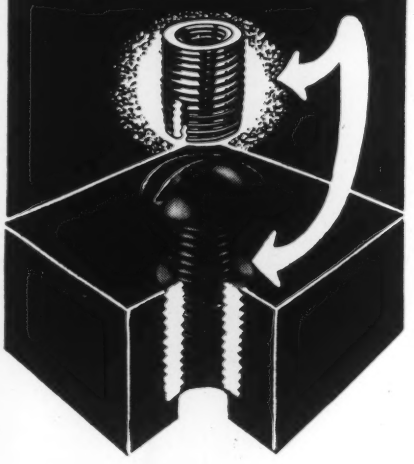
erating positions with easily accessible controls; antifriction cross-saddle mounting to insure sensitive control of cross-feed movements. Table traverses on precision roller chains; table dogs are reversible, one end spring loaded and the other a dead stop. Table swivels 90 degrees in left-hand direction and 45 degrees right. Universal cutter head adjustable for 8 to 12-in. diameters. Cutter head and tailstock provided with clearance angle setting adjustments. Attachments available to cover wide range of tool and cutter grinding operations. *International Machinery Division, British Industires Corp., New York, N. Y.*

Automatic Press: Capacity, 40 tons. Features four bronze main crankshaft bearings for longer press life. Has air-operated and electrically controlled friction clutch and brake; air ejector and cam; metered lubrication system; and cylindrical slide 16 in. in diameter guided by adjustable retainers with 380 sq in. of contact area. *Di Machine Corp., Chicago, Ill.*

Grinding Wheel Dresser: For wheels up to 36 in. diameter. Maintains accuracy of 0.0001-in. on wheels up to 14-in. diameter; 0.0005-in. on 36-in. diameter. Can be adapted to cylindrical, tool, and cutter grinders. Series of fixtures converts unit from use on surface grinder to use on any other cylindrical type grinder. Dresses two angles tangent to a radius in one continuous motion with 0.0001-in. accuracy without use of dovetails. Angles are dressed after radius is formed. Diamond returns automatically to center position. *J & S Tool Co., East Orange, N. J.*

Belt Grinder: Used primarily for free-hand applications on work requiring flat surfaces, deburring, squaring, chamfering, rounding and polishing. Grinds metal, wood, glass and plastics. Has built-in coolant system for work requiring a wet abrasive belt. Can be changed from vertical to horizontal operation in one minute by loosening two hex nuts. Equipped with standard 6-in. belt which runs over 12½-in. platen. Has two-speed pulleys for 3300 and 4000 sfpm; optional set of pulleys for 2400 and 5500 sfpm also available. Has 3-hp, 220/440-v, 60-cycle, 3-phase

TAP-LOK INSERTS
for original installations and stripped thread salvage



Tapped threads that strip easily are a headache to customers. Thread failure in light metals, plastics and similar materials can be prevented by the Tap-Lok Insert, a hard steel bushing that increases the shear area.

These Inserts are widely used for original installation because, being self-tapping, they save many man-hours in assembly. They are quickly installed with a simple driving tool into a cored or drilled hole equal in size to a tap drill hole for the external thread of the Insert. They hold rigidly in position and do not become loosened when the male part of the fastening is removed.

The Inserts are also extensively used for the salvage of threads stripped in assembly. Many manufacturers are using them for this purpose to reduce the high cost of rejects.

Send for samples and descriptive folder.

Also manufacturers of Groov-Pins for positive locking press fit.

GROOV-PIN TRADE MARK REG. U.S. PAT. OFF.

GROOV-PIN CORPORATION

1129 Hendricks Causeway, Ridgefield, N. J.

the STETSON is part of the man

JOHN B. STETSON COMPANY
PHILADELPHIA 22, PA.

Mr. C. C. Lucas
Howell Electric Motors
Broad Street Suburban Station
Philadelphia, Penna.

Dear Mr. Lucas:

It is not every day these days that a buyer can express his thanks and appreciation to a vendor for prompt compliance with scheduled delivery dates.

I want to do just that to you and, through you, to the Howell Electric Motors. While I am at it I wish to mention, also, that we are very pleased with the quality of workmanship and cleanness of design of your motors. Because our own product owes its national eminence to quality, we feel peculiarly fitted to recognize that standard in others.

With appreciation for your individual interest and the valuable cooperation of your factory, I remain

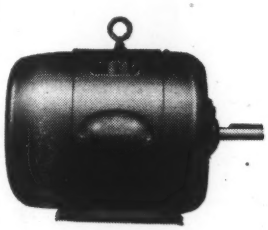
Yours very truly,

A. Kennedy, Jr.
Plant Engineer

AKjr/mc

MORE PEOPLE WEAR STETSON HATS THAN ANY OTHER BRAND

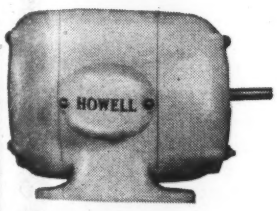
HOWELL MOTORS are part of the STETSON



HOWELL Type K Motor. Offers constant performance in the presence of dirt, dust, fumes and moisture. Sizes from 3 to 150 H.P. at 1800 R.P.M. Either vertical or horizontal mounting.

We think you, too, will appreciate Howell's attention to your electric motor problems. Howell engineers are always ready with technical assistance on motors in the standard NEMA frame sizes or with specially designed motors if your situation requires them.

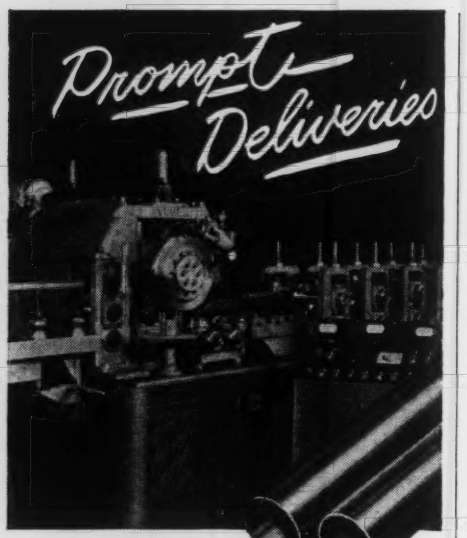
So, on the tough jobs, on every job, consult Howell — manufacturers of industrial type motors from 1/6 to 200 H.P. since 1915. Contact the Howell representative in your city or write to us direct.



HOWELL Sanitary Motors meet the most exacting standards of the dairy and food industries. They contain no pockets, cracks, or crevices. Available for vertical or horizontal mounting.

HOWELL Red Band MOTORS

HOWELL ELECTRIC MOTORS CO., HOWELL, MICH.
Precision-built Industrial Motors Since 1915



of

PIPE and TUBING

may be realized by installing a low-cost Yoder Cold-Roll-Forming, Electric-Weld Tube Mill. Cold or hot rolled strip is fed continuously into the mill, coming out as finished pipe or tubing, automatically cut to length.

Furnaces and other expensive heating equipment are entirely dispensed with, greatly reducing not only the initial investment, but also labor, maintenance and fuel cost. The only fuel needed is current for welding purposes, a negligible item of cost.

Mill speeds up to 400 feet or more per minute are practical. One operator and a helper will produce from 20,000 to 100,000 feet per 8-hour day, in sizes up to 3" o.d. For larger sizes, though speed is slower, tonnage production is greater.

You have the choice of electric resistance, induction and arc welding. Only Yoder offers you this wide choice. Yoder engineers are at your service in explaining the advantages of these respective types of welding and in determining the type best suited to your individual needs. Literature and further information for the asking.

THE YODER COMPANY
5524 Walworth Ave. • Cleveland 2, Ohio

Resistance Weld TUBE MILLS

ENGINEERING YODER MANUFACTURING

1750 rpm drive unit. Work table available. Size in horizontal position, 38 in. high, 18 in. wide, 30¾ in. deep; in vertical position, 56½ in. high, 18 in. wide, 25 in. deep. *Porter-Cable Machine Co., Syracuse, N. Y.*

Portable Impact Wrench: Features rolling ball type cam. Available with two types of spindles: size 24 with ½-in. square drive, and size 24S with 7/16-in. hexagon quick-change chuck integral with the spindle. Has side handle, trigger type throttle, and reversing valve at back. Can be equipped for either vertical or horizontal suspension on assembly lines, or for permanent locating from overhead balancers. Powered by air motor. Weighs 5¾ lb; is 8 11/16 in. long. *Independent Pneumatic Tool Co., Aurora, Ill.*

Tube Straightener: Straightens thin walled tubing to 1 in. OD and solid bar stock to ½-in. diameter. Power driven feed rolls advance tube through two sets of rolls, eight rolls to a plane. Tube does not rotate during passage. Rolls can be supplied for square or hexagon stock and tubing. *Mettler Machine Tool Inc., New Haven, Conn.*

Reaming-Tapping Machine: Reams and taps small holes simultaneously. Small brass disks are first run through drilling machine, two holes being drilled and a third hole drilled and counterbored with a combination tool for the tap. Part is then run through machine incorporating two automatic drilling units to ream previously drilled holes, and one tapping unit to tap hole. Rate of output, ten pieces per minute. Machine can be adapted to other reaming and tapping operations. *Govro-Nelson Co., Detroit, Mich.*

Cut-Off Saw: Comet MH model for nonferrous metals. Uses high-speed carbide-tipped circular saw blade to cut off aluminum shapes up to 3 by 5 in. or aluminum solids up to 2 by 4 in. Maximum capacity of vise and 12-in. saw blade is 3½ by 6 in. Work is placed in vise and foot control is depressed to actuate pneumatic - hydraulic feed ram, lock vise, and make cut. When cut is completed, saw retracts rapidly and automatically to starting position, vise opens, and work is

THIS LABEL has no substitute

There are dozens of different tracing papers, but only *one* CLEARPRINT Technical Paper. The costliest rag stock plus our exclusive life-giving treatment yields a technical paper of superior quality, unknown until the advent of CLEARPRINT.

CLEARPRINT'S perfect working surface invites pencil and ink, withstands repeated erasures and folding. Its character, strength, transparency and printing quality remain unchanged after extended exposure to age, atmosphere, heat and light.

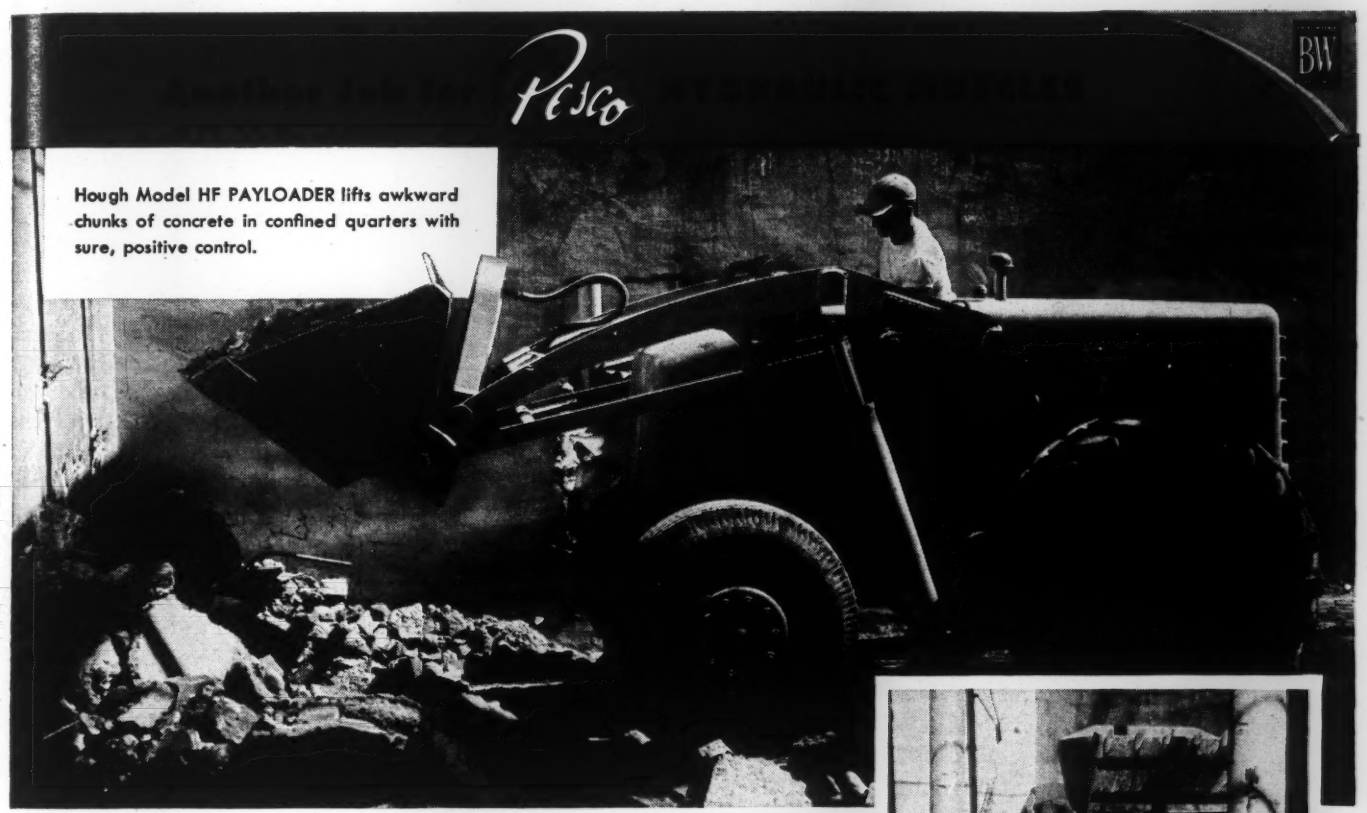
Demand and receive the one and only CLEARPRINT, tested by time and use since 1932. Available in rolls and sheets.

CLEARPRINT®

TECHNICAL PAPER

DEMAND IT—THERE IS NO SUBSTITUTE

SPECIFY: No. 1000H CLEARPRINT
the universally accepted technical paper
AND: No. 1025 PAPERCLOTH
the paper with cloth durability
Clearprint is also available in other weights
Ask for samples from your dealer, or write:
CLEARPRINT PAPER CO.
1482 Sixty-seventh St. • Emeryville, Calif.



Hough Model HF PAYLOADER lifts awkward chunks of concrete in confined quarters with sure, positive control.

Positive Pesco Power for Lift, Tilt, Dump

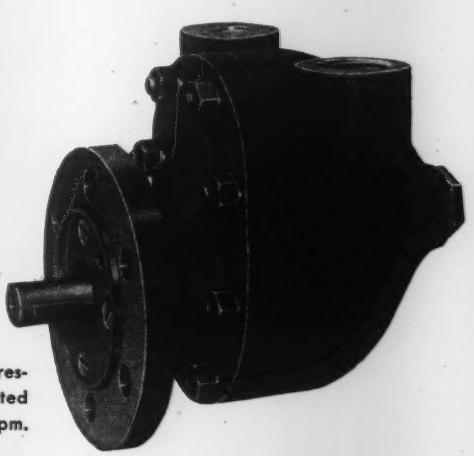
makes close-quarter work easy for a PAYLOADER®

High, sure lifts are made possible by the rugged Pesco hydraulic pump.

Hough PAYLOADERS, well known for their versatile, dependable performance rely on a small Pesco hydraulic pump as the heart of the hydraulic bucket control system. Power to spare is always on hand. The minute power is needed to dump, lift or tilt the bucket, it's there . . . right at the operators' finger tips.

Countless pumps on countless jobs, serving in all kinds of rugged conditions have made Pesco pumps famous for their dependable, trouble-free service. Behind the dependability of Pesco hydraulic equipment are years of research and practical know-how.

This knowledge can be of benefit to you. Write today stating your hydraulic problems. We will be glad to help.



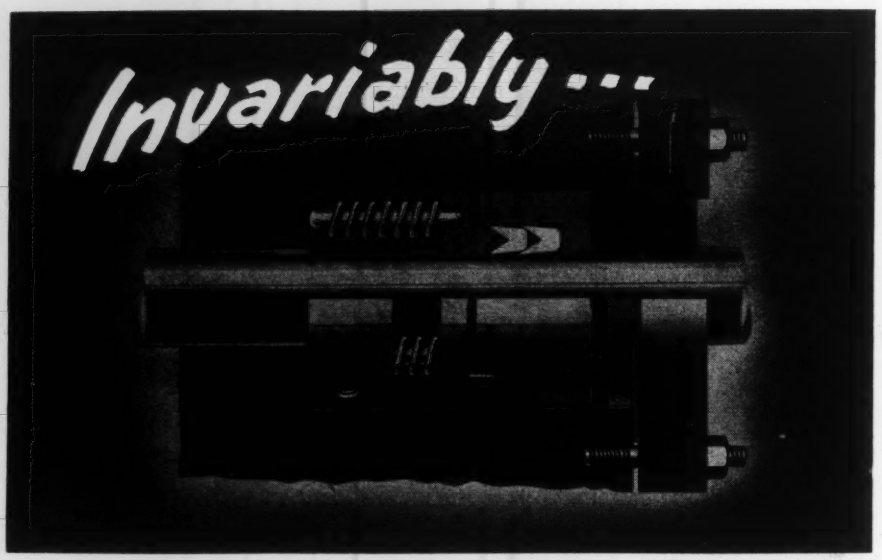
Hydraulic pump Model 051006, gear type, pressure loaded with positive displacement. Rated capacity; 15 gpm at 1000 psi and 1200 rpm.

engineering Pesco production

PRODUCTS DIVISION

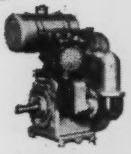
BORG-WARNER CORPORATION

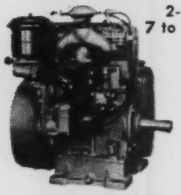
24700 NORTH MILES ROAD • BEDFORD, OHIO

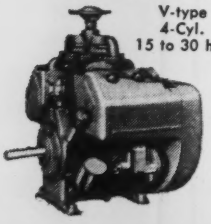


...invariably it's DURA SEAL
ROTATES WITH THE SHAFT
for long dependable service
WHERE ....ECONOMICAL OPERATION IS DESIRED
....OPERATING CONDITIONS ARE HAZARDOUS
....LOSS OF COSTLY FLUIDS MUST BE PREVENTED
....COMPLETE AND PERFECT SEALING REQUIRED
GET THE "DURA SEAL" STORY—WRITE FOR BULLETIN 174MD
DURAMETALLIC CORPORATION
KALAMAZOO MICHIGAN

Power... To Fit the Job and the Machine


Single Cyl. 3 to 9 hp.


2-Cyl. 7 to 13 hp.


V-type 4-Cyl. 15 to 30 hp.

WISCONSIN Heavy-Duty Air-Cooled ENGINES

Today, leading manufacturers of agricultural machines, construction and oil field equipment, railway maintenance equipment for both on-track and off-track operations, and many types of industrial machines employed in outdoor field service now specify Wisconsin Air-Cooled Engines as *standard* or optional power components . . . integrally mounted on their machines.

This broad acceptance may be credited to the fact that Wisconsin Air-Cooled Engines, because of their extreme compactness, light weight, economical operation and heavy-duty dependability . . . ideally fit both the *machines* and their *service requirements*.

Wisconsin Air-Cooled Engines are supplied in a complete power range, from 3 to 30 hp., in 4-cycle single cylinder, two-cylinder and V-type 4-cylinder models. We will be happy to put you in touch with the nearest Wisconsin Engine distributor and supply you with descriptive and engineering data. Your inquiry is invited.

WISCONSIN MOTOR CORPORATION
World's Largest Builders of Heavy-Duty Air-Cooled Engines
MILWAUKEE 46, WISCONSIN

released. Feed rate of ram adjustable from 0 to 24 fpm. Has 7½-hp, 3-phase, 60-cycle, 220/440-v, 3600 rpm motor with magnetic starter and pushbutton control. *Consolidated Machinery & Supply Co., Los Angeles, Calif.*

Drill Presses: Redesigned line of presses which have ½-in. capacity in cast iron and will drill to the center of a 15-in. circle. Spindle travel is 6 or 4¼ in. Six-inch spindle travel model incorporates calibrated depth gage and micrometer type depth stop. All models feature completely enclosed motor switch housings built into head casting. Four speeds ranging from 600 to 5000 rpm available. Bench, floor and multi-spindle models. *Walker-Turner Div., Kearney & Trecker Corp., Plainfield, N. J.*

Table Jointers: Six and 8-in. models of all steel construction. Feature quick, positive, micrometer-accurate knife-setting system which assures smooth operation and better finish. Ground steel bar is employed as positive setting stop. Knife ends are raised by screw lifter to micrometer-accurate setting. All knives cut the same depth within 0.002 to 0.003-in. The 8-in. model has four knives, and the 6-in. model, three, delivering 14,400 and 10,800 cuts per minute, respectively. Have full length, front-adjusting, double locked fences. *Boice Crane Co., Toledo, O.*

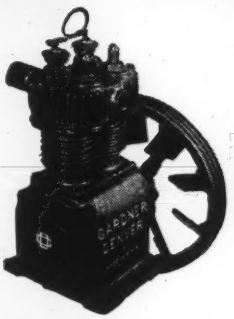
Packaging Machinery

Labeler: Combination unit attaches ungummed or pregummed labels to various types of containers; will also handle heat-activated labels. Handles various sizes of labels and containers. Can be operated on a straight line or at almost any angle to capping line. Adhesive or water is sprayed on ungummed or pregummed lables, respectively, and label is wiped onto container. Model also available for heat-activated labels only. *Able Engineering Inc., Minneapolis, Minn.*

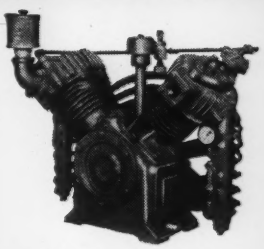
Filling Scale: For net-weighing and bagging bulk materials such as chemicals, plastics, grain, etc. Equipped with self-gripping bag holder, automatic net-weighing hopper, supply tube whose opening may be varied up to 72 sq in., air-operated feeding gate, and auto-

START saving compressed air costs HERE...

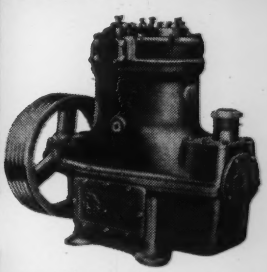
Dependable compressed air can cost less when one of these efficient, high-grade Gardner-Denver Compressors is an integral part of the machinery you design. There's a size to fit your capacity and pressure requirements exactly.



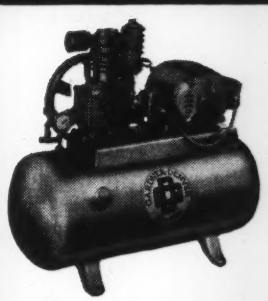
Single- or Two-Stage Air-Cooled Compressors for pressures up to 250 lbs.—piston displacements to 36 cubic feet per minute.



Air-Cooled V-Type Two-Stage Compressors for pressures up to 250 lbs.—piston displacements to 72 cubic feet per minute.



AA Single-Stage Water-Cooled — for pressures to 150 lbs. — capacities to 183.6 cu. ft. displ. per min. Two-stage model for pressures to 1000 lbs.



Complete Tank-Mounted Compressor Outfits. Single-Stage or Two-Stage in wide capacity range. Electric motor or gasoline engine drive.

Our experienced field engineers will help you select the right compressor unit for your needs. Write for details and full specifications.

SINCE 1859

GARDNER-DENVER

Gardner-Denver Company, Quincy, Illinois

In Canada: Gardner-Denver Company (Canada) Ltd., Toronto, Ontario

THE QUALITY LEADER IN COMPRESSORS, PUMPS AND ROCK DRILLS

What do you know about the *Moly-sulfide* LUBRICANT?

You may have heard rumors of a highly successful solid-film lubricant which is giving remarkable results in the shop and in the field.

In one 40-page booklet we have collected 154 detailed case-histories describing how difficult lubrication problems have been overcome by molybdenum sulfide. If you wish to be up to date about this solid-film lubricant, write for a free copy now.

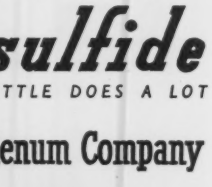
THE LUBRICANT OF MANY USES

Moly-sulfide

A LITTLE DOES A LOT

Climax Molybdenum Company

500 Fifth Avenue
New York City



SEND FOR THIS FREE BOOKLET TODAY

Name.....
Position.....
Company.....
Address.....

MOLY

MD4 MS-3

matic check-weighing and bag-releasing system. Shock-proof leverage scale operates without use of knife-edge pivots, holding original sensitivity and accuracy indefinitely. Feeding system utilizes both gravity and vibration. Adjustable, flood-proof feeding gate partially closes when net-weighing hopper is filled to about 95 per cent of predetermined weight. Material is then dribble-fed by means of vibration until desired weight is reached. Size of unit: 2 by 4 by 6 ft high. Duplex units also available. *Thayer Scale and Engineering Corp., Rockland, Mass.*

Plant Equipment

Web Type Filter: Has self-clean-continuously rotating filter web. For all types of grinding, broaching, drilling, lapping, milling machines, etc.; wherever a mineral or soluble oil coolant is used. Contaminated coolant flows by gravity or system pressure over surface of rotating filter belt and passes through web into clean-coolant tank. Chips, abrasives and other solid particles are carried off by moving web and deposited into chip pan or hopper underneath filter unit. Beaters shake out foreign particles as web passes over chip pan. Filtered coolant is then pumped back to machine sumps. Speed of web and degree of filtration are variable. Available in capacities from 40 to 500 gpm. Size of 50 gpm model, 47 by 42 by 30 in. *Honan-Crane Corp., Lebanon, Ind.*

Die Lift Tables: Standard table sizes from 30 by 36 in. to 44 by 84 in., with capacities from 4 to 10 tons. Elevations from 30 to 46 in. Mechanically operated; air or hydraulically operated units also available. Features include four-point support, magnetic reversing starter, transformer for 110-v operation, pushbutton control, positive truck locks and protective skirts for full elevation. Variations available for special applications. *The Union Tool Corp., Warsaw, Ind.*

Hydraulic Power Unit: For heavy-duty, portable machine provides hydraulic power for testing equipment, modernizing older machinery and for emergency hydraulic power. Especially suited to aviation and automotive equipment

Newspaper classified columns are full of ads for engineers, chemists, technicians. Employment agencies are besieged with requests for trained technical men.

Yet many concerns do not realize that the best source of trained help may lie right within their own organizations.

How can you tap this fertile source?

The answer is simple. Release your technical men from routine testing jobs. Give them the promotions they earnestly desire . . . give them responsibility . . . put them where their talents and training are used at full potential.

And then turn over your routine testing to us. We can handle it efficiently . . . and probably at lower real costs. We have specially trained engineers, chemists, biologists, physicists, and technicians . . . and at their disposal is a comprehensive array of scientific equipment.

Let's get together and discuss this matter. You may find your "help wanted" problems well on their way to solution . . . and at savings to you!

UNITED STATES TESTING COMPANY, Inc.

Established 1880
1500 Park Avenue, Hoboken, N. J.
PHILADELPHIA • BOSTON • PROVIDENCE
CHICAGO • NEW YORK • LOS ANGELES
MEMPHIS • DENVER • DALLAS
Member of American Council of Commercial Laboratories

Short Cut to Better Bearing Performance

Single Pillow Block with Labyrinth Seal

If you are a manufacturer of fans and blowers or any other equipment where bearings are essential, you can often get the advantages of ball bearings without using "specials" that run up your costs. Here's how!

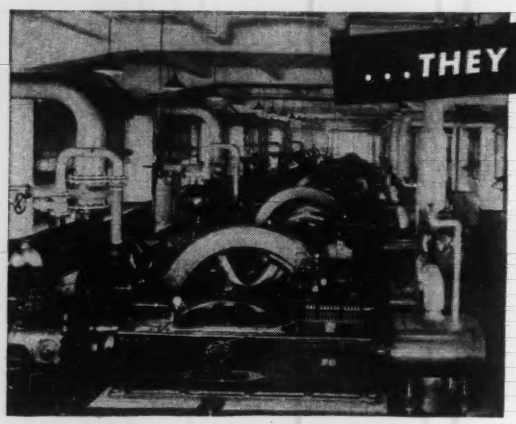
With Fafnir Standard Ball Bearing Units, you cut costs two ways: (1) the cost of the unit as compared with "Specials" and (2) the elimination of complicated machining and special housings. In addition, installation costs are pared way down because these units have the famous Fafnir Wide Inner Ring Ball Bearing with self-locking collar . . . makes adapters, sleeves and lock washers unnecessary. Seals keep lubricant in, dirt out. Now you know why we call these Fafnir units "Economy Packages".

Whatever your product or plant equipment . . . a few minutes spent with a Fafnir representative may bring forth an "Economy Package" that provides a short cut for you to the kind of performance only ball bearings can give.
The Fafnir Bearing Company, New Britain, Conn.

FAFNIR
BALL BEARINGS
MOST COMPLETE LINE IN AMERICA

LEADING PUMPS AND COMPRESSORS HAVE

Manzel FORCE FEED LUBRICATORS



...THEY NEVER FORGET

Worthington Compressors in an automobile plant, with Manzel Model 94 Lubricators

- Manzel lubricators supply each wearing point with exactly the amount of oil it needs, and *no more.* Thus they reduce oil consumption as much as 90%.

"Manzels" are furnished as standard equipment on leading makes of engines and machinery. Or they can be installed on your present equipment.

We will gladly have a Manzel lubricator engineer submit recommendations without obligation.

Just write...

Why it Pays to Select Manzel Lubricators

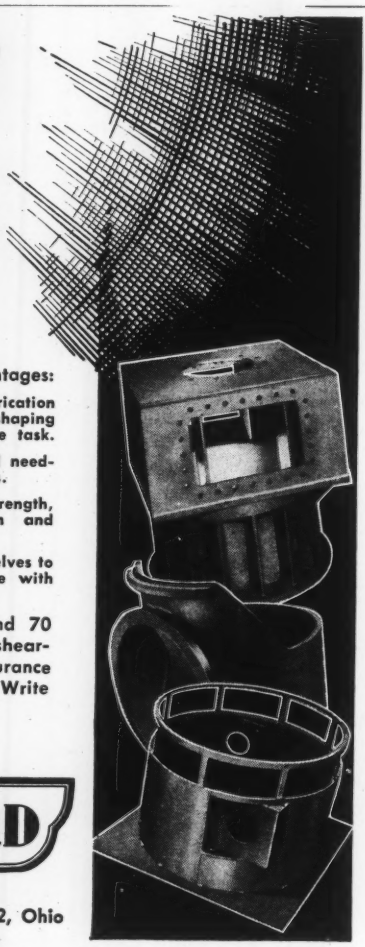
- THEY LENGTHEN THE LIFE OF MACHINERY
- THEY ARE AUTOMATIC AND TROUBLE-FREE
- THEY ELIMINATE "DOWN TIME"
- THEY CORRECTLY LUBRICATE EACH POINT

Manzel

276 BABCOCK STREET
BUFFALO, NEW YORK

Weldments

BY LITTLEFORD INSURE PRODUCTION ECONOMY & QUALITY



Littleford Weldments have four basic advantages:

1. MODERN DESIGN—Welded metal fabrication lends itself to efficient, modern design shaping metal on modern equipment is a simple task.
2. LESS WEIGHT AND BULK—Unwieldy and needless weight are eliminated in Weldments.
3. STURDY—Weldments have inherent strength, toughness to withstand shock, strain and vibration.
4. ADAPTABILITY—Weldments adapt themselves to changes and improvements at any time with minimum of cost.

Littleford complete fabricating service and 70 years experience in laying out, forming, shearing and welding all types of metals is assurance of quality weldments regardless of size. Write for Weldment Bulletin.

LITTLEFORD

LITTLEFORD BROS., INC.
424 E. Pearl Street, Cincinnati 2, Ohio

testing and the powering of machine tools and processing machinery. Has fixed volume pump. Handwheel and pressure compensated controls enable user to meet specific job needs up to 5000 psi and 75 hp. Has micronic filter, built-in relief valve, flowmeter, pressure gages and electric controls. *The Rucker Co., Oakland, Calif.*

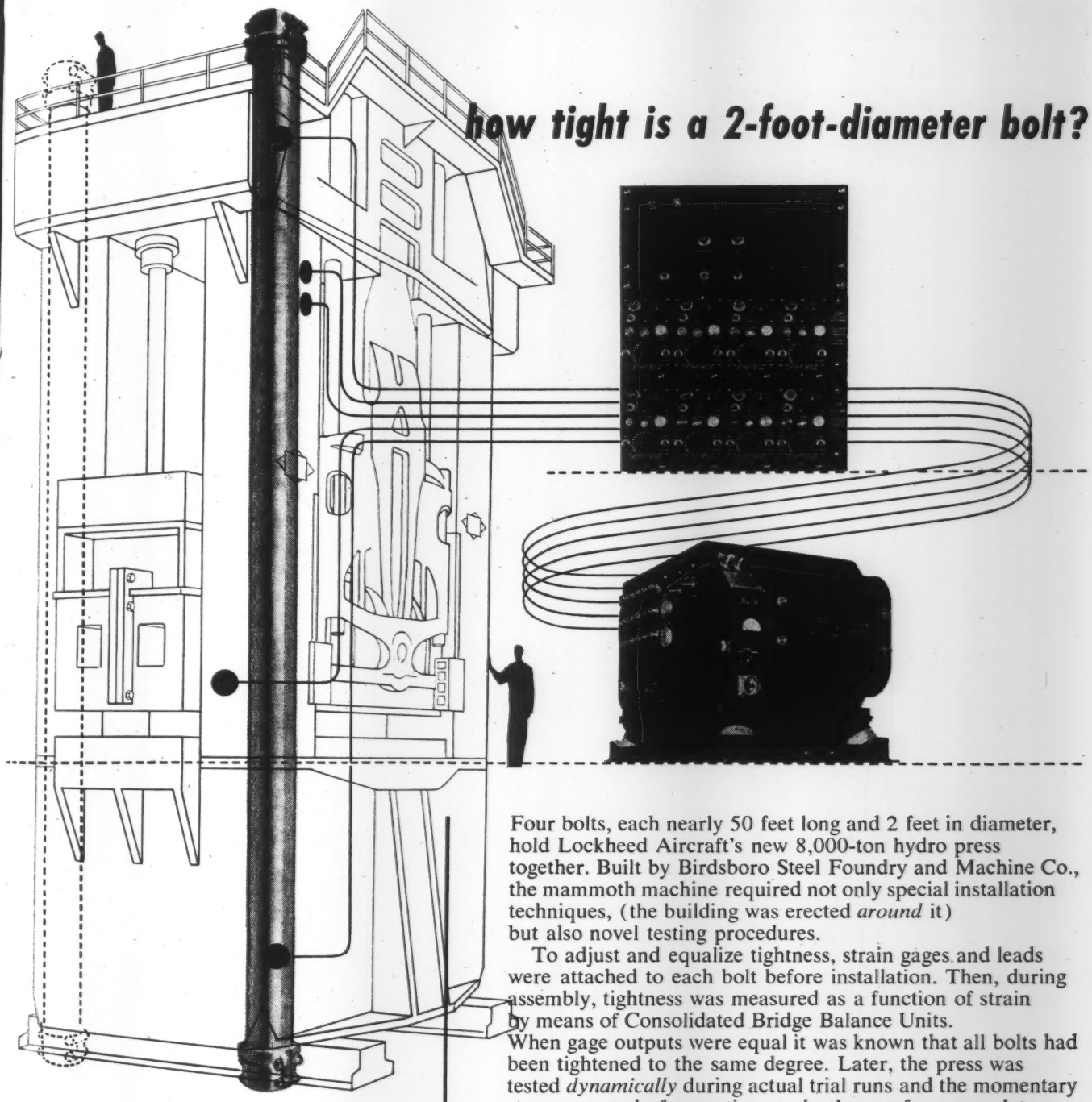
Welder's Truck: Accommodates one gas and one air cylinder. Swivel-mounted tool box for torches, tips, etc., located between handles. Torch hanger may be mounted on cross bar of handle. Has metal wheels. Overall height, 48 in.; width, 29 in. Approximate weight 125 lb. *The Palmer-Shile Co., Detroit, Mich.*

Hydraulic Power Package: Model S-440, for oil or water service, is applicable for wide variety of uses where low volume output at high pressure is required, such as in hydrostatic testing. Uses either oil or water as testing medium. Operates automatically on the principle of differential areas. Furnished in six standard models with ratios of from 35:1 to 300:1, making possible output range from 3500 to 30,000 psi. Size, 12 by 12 by 24 in.; weight, 45 lb. *Sprague Engineering & Sales Corp., Gardena, Calif.*

Water-Oil Separator: Used for turbine, hydraulic oils, or any industrial oil purification problem where water is a troublesome factor. Claimed to reduce water content of oil to less than 0.1 per cent and to eliminate necessity for changing or discarding oil. Performs complete filtering service for removal of solid contamination, acids and other sludge-forming products of oxidation as well as water separation. *Honan-Crane Corp., Lebanon, Ind.*

Dust Collector: Self-contained, portable unit will collect dust from as many as ten grinding wheels in simultaneous operations. Capacity, 3630 cfm at a static suction of 6 in. measured on an 8-in. inlet pipe. Air is drawn into collector by means of self-clearing paddle wheel fan driven by 5-hp motor. First stage cleaner is cyclone separator of predetermined operating efficiency; second stage is heavily compressed fiberglass filter which

how tight is a 2-foot-diameter bolt?



Four bolts, each nearly 50 feet long and 2 feet in diameter, hold Lockheed Aircraft's new 8,000-ton hydro press together. Built by Birdsboro Steel Foundry and Machine Co., the mammoth machine required not only special installation techniques, (the building was erected *around* it) but also novel testing procedures.

To adjust and equalize tightness, strain gages and leads were attached to each bolt before installation. Then, during assembly, tightness was measured as a function of strain by means of Consolidated Bridge Balance Units. When gage outputs were equal it was known that all bolts had been tightened to the same degree. Later, the press was tested *dynamically* during actual trial runs and the momentary stresses, speed of operation, and other performance data recorded by a 5-114 Recording Oscillograph. The *complete* performance picture, with all forces in their true relationship, gave Birdsboro and Lockheed engineers all information needed for the final adjustments necessary for optimum operation before actual production work started.

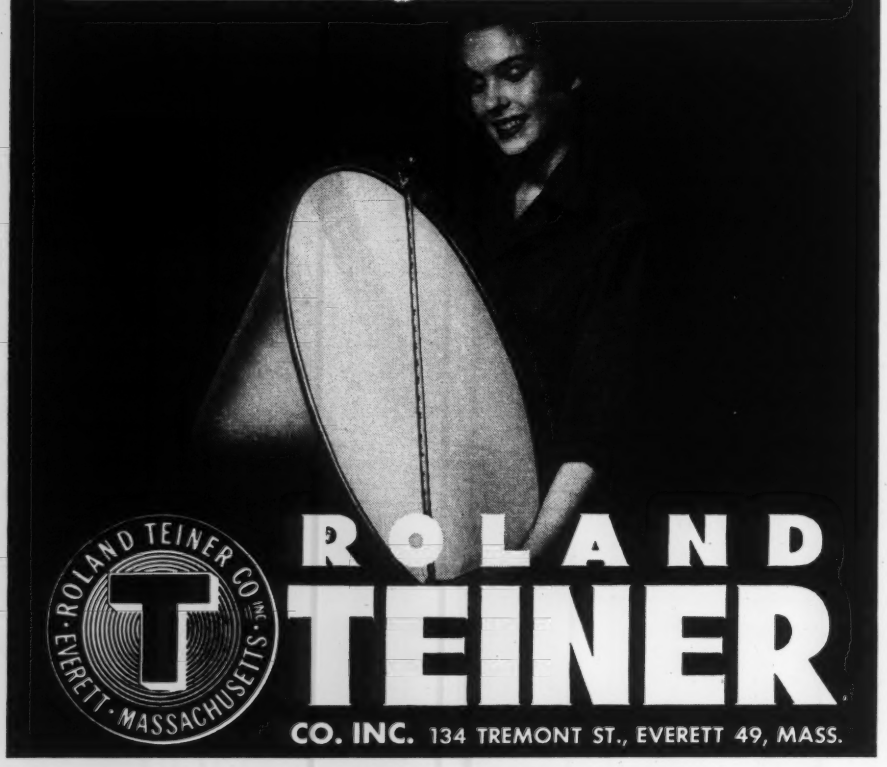
consolidated recording oscillograph

The 5-114 Recording Oscillograph is used for multichannel testing of hundreds of widely varying products from trains to rocket-propelled planes, from small valves to entire oil-drilling derricks. Write for Bulletin 1500B.

CONSOLIDATED ENGINEERING CORPORATION

Analytical Instruments for Science and Industry
300 No. Sierra Madre Villa
Pasadena 8, California

FILLING AN EXPERIMENTAL ORDER. Measuring 24 inches, large TV cone, spun of special formula stainless steel, illustrates type of experimental work suitable for mass production by automatic spinning. An example of the all-gage — all-metal — any quantity — spinning capacity available at Teiner. *Write for newest color brochure* 51M.



ROLAND TEINER CO. INC. EVERETT · MASSACHUSETTS

ROLAND TEINER

CO. INC. 134 TREMONT ST., EVERETT 49, MASS.

Do You Want To Pump HEAVY LIQUIDS?

. . And by this, we mean not only a liquid with high specific gravity like molten lead, but one that is thick, viscous or semi-solid like paint, tar or peanut butter.

The *positive* "gear within a gear" Viking rotary pump does the job right. Its simple design (only 2-moving parts) makes it economical to buy, low in cost to operate and extremely easy to service.

Its size range, ½ to 1050 gpm, and its adaption to any mounting arrangement, makes it the positive pump of the design engineer.

Its simple, rugged design makes it the preferred pump of the operator. Both get a break when VIKING is specified.

(Did you know Vikings will operate equally well handling light liquids too . . . as light as liquefied petroleum gas?)

Send for descriptive 8-page folder today . . Series 52SH.

See Our Catalog In SWEETS

Viking PUMP COMPANY Cedar Falls, Iowa

cleans air and returns it to working space, thereby saving heat. Uses 220 or 440-v, 3-phase, 60-cycle power. Floor size, 29 by 50 in.; height, 132 in. *Aget-Detroit Co., Ann Arbor, Mich.*

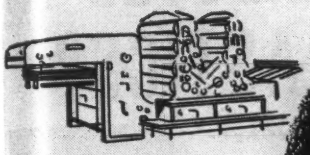
Oxygen Generator: Composed of series of automatic reversing heat exchangers which eliminate need for chemical purification of the air. Has few moving parts. Produces 99.5 per cent pure oxygen. Models range from ½ to 12 tons daily capacity. *Joy Manufacturing Co., Pittsburgh, Pa.*

Industrial Vacuum Cleaner: Picks up either liquid or dry dirt without adjustment or change of parts. Has 55-gal tank, which holds 5 bu of dry dirt or 40 gal of recovered liquid, mounted on heavy steel dolly. A 2-in. quick-opening gate valve permits emptying liquid contents. Has 20-ft hose made of oil-resistant, wire-reinforced, synthetic rubber. Separate fan cools motor; thus protecting motor from damage by dust or moisture picked up by vacuum. *Hild Floor Machine Co., Chicago, Ill.*

Processing Equipment

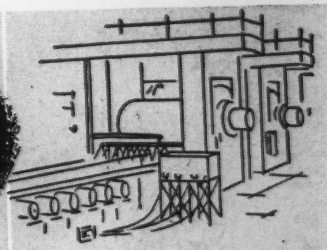
Cleaning Machine: For cleaning delicate parts. Has three windows on motor support for instant checking while machine is in operation. Spun aluminum tanks are 10 in. high; 10 in. in diameter; have 4-gal capacity. Basket is 7 3/16 in. in diameter; 3¾ in. deep; has three removable mesh compartments for cleaning a variety of parts simultaneously. Basket snaps onto impeller shaft. Inner steel tube of center supporting column is splined for automatic centering over tanks and dryer. Has 14 to 1 gear reduction, ball bearing, ac-dc motor with reversing action. Size: 23¼ by 26¼ by 26 in. high. *Zenith Manufacturing and Chemical Corp., New York, N. Y.*

Industrial Electric Heaters: Two models for use in chemical, plastics, paint, metalworking and finishing industries. Type TBL electric tank heater has vapor-tight terminal box. Heavy-duty tubular elements are welded to sealed electrical connection housing, and wiring is brought out to terminal box through thick-walled steel pipe. L-shaped unit available in steel, alloy or stainless, with ratings from 3 to 7.5 kw. Heated height

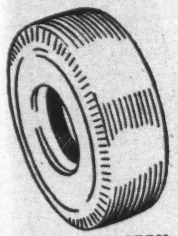


PRINTING INDUSTRY

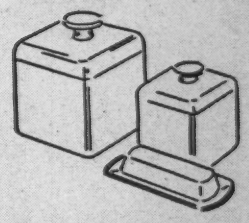
It's the EXPERIENCE that counts...



STEEL INDUSTRY



RUBBER INDUSTRY

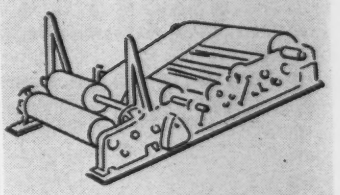


PLASTICS INDUSTRY

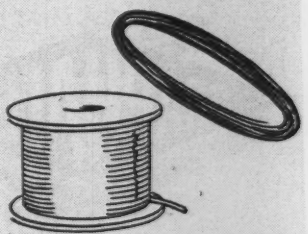
in providing OPERATOR CONVENIENCE through machine design

By working closely with machinery manufacturers and users, Reliance has constantly simplified the control of drive equipment to improve the productivity of machinery. Production is increased because controls of the Reliance V★S Drive are placed where the operator can conveniently select the right speed for each operation. Because operator fatigue is reduced, there is less production lag—scrap losses are held to a minimum. Write today for new V★S Drive Bulletin D-2311.

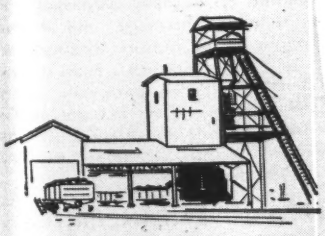
FOOD INDUSTRY



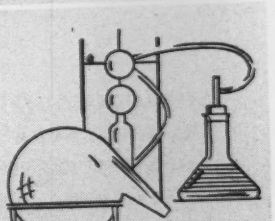
PAPER INDUSTRY



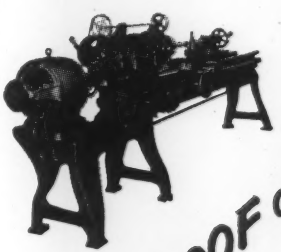
WIRE AND CABLE INDUSTRY



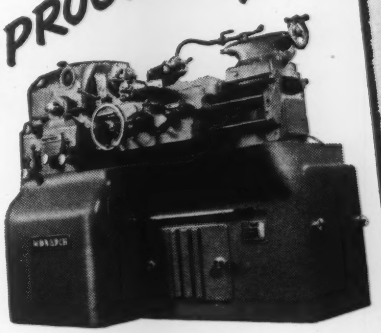
MINING INDUSTRY



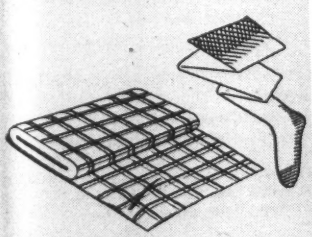
CHEMICAL INDUSTRY



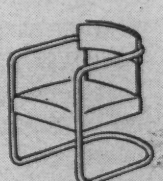
PROOF of PROGRESS!



Just after the turn of the century, the lathe above made news with its adjustable-speed Reliance Armature-shifting Motor. Modern lathes (right) have built-in Reliance V★S Drives to provide control of all functions of spindle and speeds.



TEXTILE INDUSTRY

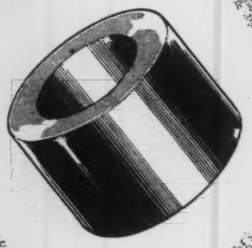


METAL FABRICATING INDUSTRY

RELIANCE ELECTRIC AND ENGINEERING CO.

1079 Ivanhoe Road, Cleveland 10, Ohio • Sales Representatives in Principal Cities

WORKS WHERE OTHERS WON'T



accurately formed

GRAPHALLOY OILLESS BEARINGS

SPECIFY GRAPHALLOY TRADE MARK REG. U. S. PAT. OFF. WITH CONFIDENCE

SELF-LUBRICATING ● EXTREMELY DURABLE ● CONSTANT CO-EFFICIENT OF FRICTION ● OPERATES DRY — *OR SUBMERGED IN WATER, GASOLINE OR CORROSIVE LIQUIDS* ● APPLICABLE OVER A WIDE TEMPERATURE RANGE — *even where oil solidifies or carbonizes* ● EXCELLENT AS A CURRENT-CARRYING BEARING.

GRAPHITE METALLIZING CORPORATION

1045 NEPPERHAN AVENUE, YONKERS 3, NEW YORK

ranges from 11⅛ to 43¾ in., and heated base, from 13 7/16 to 25 9/16 in. Type ARMT screw-plug unit has explosion-proof or vapor-tight terminal box. Constructed of brass or copper for water heating in 50 to 250 F range; constructed of steel for oil heating in 150 to 550 F range. Available with 2 and 2½ in. standard pipe thread fittings in ratings from 1.5 to 10 kw. Heated length ranges from 7¾ to 48 in. *E. L. Wiegand Co., Pittsburgh, Pa.*

Chrome Plating Equipment: For industrial plating of small tools or parts in large quantities, or large parts with areas up to 125 sq in. Power unit contains built-in selenium rectifier with instrument panel and controls for regulating rate of chrome deposit. Average plating time for cutting tools is 3½ minutes. *Industrial Chrome Div., Ward Leonard Electric Co., Mount Vernon, N. Y.*

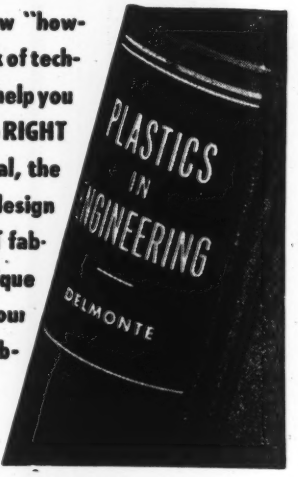
Mechanical Finishing Machine: For disk type circular parts. Utilizes rotary tumbling action and directional flow of finishing media to produce desired results. Has 30⅛-in. long by 35¼-in. ID rubber-lined compartment with 18-cu ft capacity. Features pushbutton operation with all controls located on one panel. Automatic timer is available to control operation for as long as 20 hours. Speed of cylinder variable from 10 to 30 rpm. *Roto-Finish Co., Kalamazoo, Mich.*

Chilling Machine: Capacity, 5 cu ft. Maintains temperatures as low as −120 F. For use in small heat treating departments. Also of use in lengthening life of perishable tools and in saving time by contracting parts for shrink fit assembly work. *Sub-Zero Products Manufacturing Div., Deepfreeze Distributing Corp., Cincinnati, O.*

Mineral Spirits Washer: Designed especially for one-man operation. Loading and unloading accomplished by use of return-type conveyor. Cleaning cycle consists of two washing stages and a forced-air blow-off. Adjustable spray nozzles provide even, all-over coverage of parts being cleaned. Safety features include explosion-proof switches and motors, nonferrous metal moving parts, complete exhaust system, and automatically actuated carbon dioxide system. *Detrex Corp., Detroit, Mich.*

INTERESTED IN PLASTICS?

This brand new "how-to-do-it" book of technical data will help you determine the RIGHT plastic material, the RIGHT mold design and the RIGHT fabricating technique to solve your plastics problem.



"Plastics in Engineering" by John Delmonte is not an elementary text. It's an important working "tool" for everyday reference by designers, engineers and users of plastics.

Written in the language of men who use plastics in design and production, "Plastics in Engineering" is one of the most valuable additions you can make to your technical library.

You'll find it a veritable gold mine of engineering data on methods of fabrication, the advantages and limitations of various materials and the chemical and physical characteristics of plastics.

You'll have scores of up-to-the-minute facts about plastics right at your fingertips: How strong various plastics are—for what uses they are best suited—how to design plastic parts—how these remarkable synthetic materials are molded, extruded, laminated, cast—how much heat they will stand—how to guard against failure—how to machine plastics and other vital factors that are so essential to satisfactory plastics performance.

Over six-hundred pages, fully illustrated with photographs, detailed drawings and tables, cover every phase of the plastics industry from raw material to finished product. From its first chapter which dips into the intriguing history and development of the plastics industry, to the last chapter which reveals the primary cost factors in producing plastics, it covers its field thoroughly and authentically.

PLASTICS IN ENGINEERING
(Completely Revised Third Edition)
by John Delmonte
Technical Director, Plastic Industries' Technical Institute

SEND FOR YOUR COPY TODAY

THE PENTON PUBLISHING COMPANY, MD-11-50
Book Department
1213 West Third St., Cleveland 13, Ohio

Send me a copy of "Plastics in Engineering" by John Delmonte.

☐ On ten days trial for free examination, following which I will either pay for the book at $10. plus postage, or return it in good condition.

☐ C.O.D.

☐ Remittance enclosed* in which case the book will be sent postpaid.

SIGNED: ..... TITLE: .....

COMPANY: .....

ADDRESS: .....

CITY: ..... ZONE ... STATE

*On orders for delivery in Ohio please add 30c to cover state sales tax.

"customer conscious..."

You are treated like a customer when you deal with The Bunting Brass & Bronze Company. It is a tradition in the Bunting organization to consider the good will of the customer as the most important factor in the transaction. Bunting customers find that Bunting resourcefulness no less than Bunting products, is made available when needed . . . Ask any Bunting customer.

The sleeve bearing is not complex in structure; it conforms readily to design requirements; it is easily installed. Cast Bearing Bronze is the most adaptable of all sleeve bearing materials; it possesses excellent anti-friction properties. With proper film lubrication, its coefficient of friction is as low as can be obtained with any other bearing type. A successful Bunting Bronze bearing installation is readily attainable. We ask the opportunity to work with you, and to quote on your requirements.

Bunting®

BRONZE BEARINGS • PRECISION BRONZE BARS • BUSHINGS

THE BUNTING BRASS & BRONZE COMPANY • TOLEDO 1, OHIO • BRANCHES IN PRINCIPAL CITIES